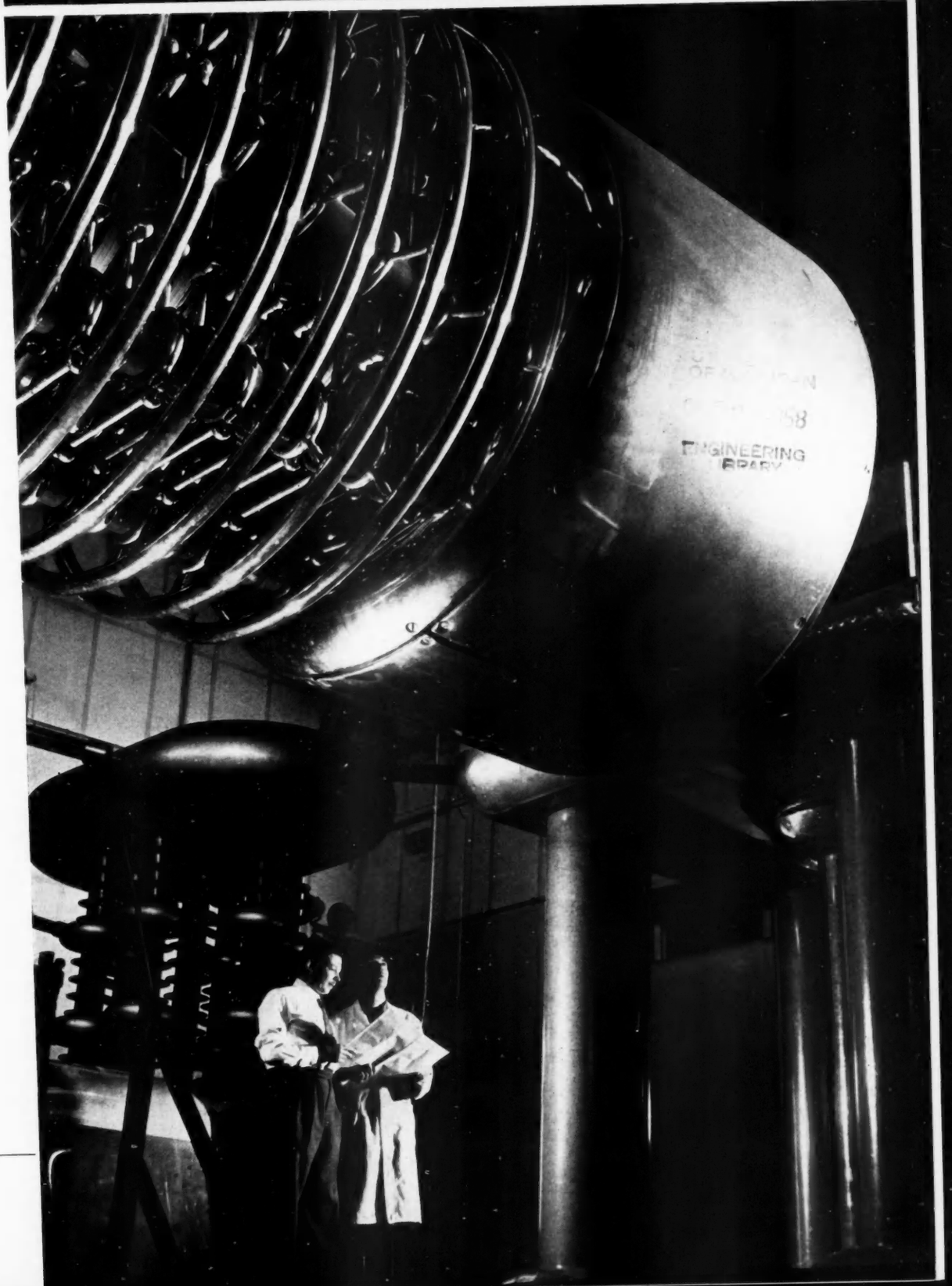
ENGINEERING



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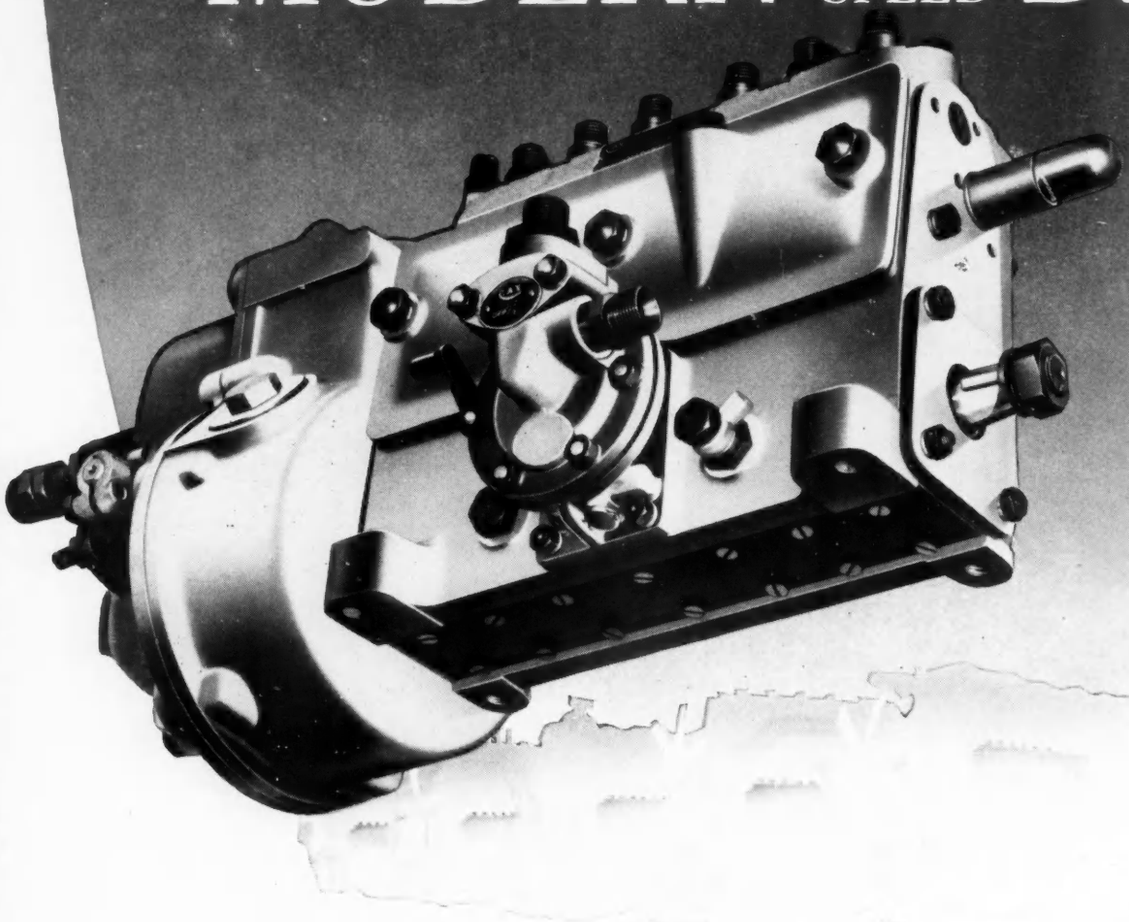

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ENGINEERING

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Monte Carlo Method

THERE must be many people like Harry Ballantyne who have set out on a promising career only to find five years later that it has come to a dead end. Harry read chemical engineering at Liverpool where he became attracted to nuclear science—and incidentally to a certain young lady whom he subsequently married. After graduating he entered an atomic energy establishment and because of his chemical engineering background joined a team working on the aqueous homogeneous reactor. The idea that the fuel, being in solution, could be continuously processed and that fresh fuel bred in an outer jacket might constantly be fed in to replenish the central core appealed to him immensely.

But conditions changed. Financial resources turned out to be inadequate, a rival reactor system, having made a good start, was adopted as the national choice, on which the major development effort was to be concentrated. Sealing and corrosion problems proved to be quite formidable in the homogeneous system and their solution costly; while the abundance of uranium supplies made breeding a less urgent requirement. It did not come as a great surprise to Harry, therefore, when eventually the aqueous homogeneous project was abandoned. Harry was transferred to a more favoured project, but came in with a disadvantage, since his new companions were already well established. After some months, he left to join a commercial group who had turned their attention to long-term studies of advanced and exotic reactor systems.

Harry was not embittered. He had discussed the situation with his wife, who had pointed out that within their terms of reference the Government's advisers were taking the sensible, indeed the only, course. After all, it was largely a matter of chance—"look at those fusion chaps who had the luck to work under Sir George Thomson; they're right in the limelight now, but they couldn't have known the outcome when they first chose to study physics."

But Harry could not avoid the irrational suspicion that if he'd had his eyes wide open it need not have happened. That is why when he had the opportunity to represent his firm at the second Geneva atomic energy conference, he took it like a shot. He hadn't heard that people went to conferences to pick their jobs, but that was his intention. He is no doubt making his final decision at this moment as the conference draws to a close.

So doubtless is his company. They may be wondering if atomic energy is a good business to be in. Professor Perrin in his presidential address to the conference underlined the warning that "in the near future atomic energy can play an important part only in a fairly restricted range of countries"—countries in fact that are well equipped to help themselves. Some say that there are too many instrument firms struggling for a place; others that fragmentary development contracts granted by the Authority are not enough. Recent entrants into the field appear to consider it best to remain independent of the major groups. Others, knowing that in order to retrieve the cost of large-scale power-reactor development a consortium must win a given quota of power-station contracts, declare that five groups are too many. However, the national interest may require five groups, and the view of the authorities will become apparent when the contracts for Trawsfynydd and Dungeness are awarded, since without work no group can continue to employ a large research team. But certainly if the nation does not want five consortia it should have been made clear long ago, and the placing of these two contracts cannot but be interpreted as a decisive, if belated vote of confidence.

But what of the other groups who ambitiously espoused advanced reactor systems at an early stage, in some cases to the displeasure of those responsible for formulating national policy? With the decision to concentrate on one system only, information on other schemes dried up. To meet this situation, a number of British firms formed associations with American companies, thereby securing other sources of data. It is rumoured that when the Government had to turn to the United States for details of a particular reactor, the American corporation concerned pressed for the employment of a certain British company as subcontractor. But in the long run what is to be the function of these adventurous groups who seem to be sitting this one out? It may be that while the five consortia are deeply committed to current reactor projects, the supernumerary groups will provide a means of leap-frogging into the future.

The distant future is more difficult to foresee. British policy appears consistent in that as with the fission reactor we have chosen to concentrate on one approach to thermonuclear research. Unfortunately the problems are dissimilar: the gas-cooled reactor was a good gamble in that one basic system could be developed virtually in isolation; but a practical fusion reactor may be a combination of several systems. Like Harry, anyone can be unlucky.

Cover Picture.—*Injector for the 50 MeV proton linear accelerator at the Atomic Energy Research Establishment, Harwell. In the background is a Cockcroft-Walton high-voltage generator. By accelerating nuclear particles to high energies and directing them at targets, something may be learnt concerning the ultimate constitution of matter.*

* * *

Plain Words

Look in the latest programmes of *My Fair Lady* and you'll find an open letter from Mr. I. J. Pitman, M.P. He writes about the new British alphabet which George Bernard Shaw took steps to introduce when he drew up his will. The Public Trustee is offering a prize of £500 for a suitable design of alphabet, the competition for which closes on 1 January next.

If you would like to have particulars of the will and the prize you are invited to send a foolscap stamped (4½*d.*) addressed envelope to the Public Trustee, Kingsway, London, W.C.2. In return you will get the particulars you asked for and also a copy of a letter which Shaw wrote to *The Times* on the subject in 1945. I wonder if your opinion, when you've read through the papers, will be similar to mine. I find it hard to believe that anyone would oppose Shaw's plan—a plan which could eventually save as much as £3,000,000 a day. Yet his will *was opposed in the Courts*. There was opposition during his lifetime, too. "I have appealed," he wrote in his letter, "to every public department whose functions are in any way relevant to take this matter up: but, with the single exception of the scientific workers, they all agree politely that it is important, but not their job."

I think, the "scientific workers"—whoever they were—showed more commonsense and foresight than the educational and literary folk. They realised, as Shaw did, "how much money there is in a British alphabet with which every sound in our speech can be written with one graphic and easily written symbol without even crosses or dots." The word "though" has two sounds, and with the new alphabet it would be written with two letters instead of the six that are now required. The new alphabet has to provide for 24 consonants and not less than 16 vowel sounds, so it will have 40 letters, or perhaps a few over 40. Mr. Pitman maintains that we would be able to read in the new alphabet after a few hours of intensive study. Then, a given passage in the English language would take up considerably less space, involve correspondingly less work, and at the same time the spelling of every word would indicate its pronunciation.

I expect you will be thinking of snags and difficulties, but I haven't got space here to give you all the answers—most of them are in the papers to which I have referred. My reason for raising the topic in this column is a simple one—that I believe engineers and other "scientific workers," and indeed many people in industry, are better able to appreciate the immense possibilities of Shaw's plan than are literary men. And I am sure that industry's output of words is much greater than the literary output. Apart from direct savings in time and money, would not the new alphabet be a great help with the translation machines which are now being developed, and perhaps already with data processing equipment? I implore you to get those papers from the Public Trustee and examine the whole thing for yourself.

CAPRICORN

P.S.—In Shaw's play *John Bull's Other Island* (written in 1904) there is a firm of civil engineers, of Great George Street, Westminster, called Doyle and Broadbent. Says Broadbent to Doyle: "You Irish people are amazingly clever. Of course it's all tommy rot; but it's so brilliant, you know! How the dickens do you think of such things? You really must write an article about it: they'll pay you something for it. If Nature won't have it, I can get it into Engineering for you: I know the editor."

Weekly Survey

Way the Fuel Goes

Last week saw the publication, by Her Majesty's Stationery Office, of the Ministry of Power Statistical Digest 1957. Total United Kingdom consumption of all fuels expressed as coal equivalent fell in 1957 for the first time since 1952 and amounted to 246·6 million tons compared with 253·9 million tons in 1956. Over the ten years 1947 to 1957, total fuel consumption has risen by 17·4 per cent but this has masked considerable variations in the trend of consumption of individual fuels. The direct use of coal has shown little change over this period, rising from 112·1 million tons in 1947 to a peak of 119·0 million tons in 1951 and subsequently falling to 106·2 million tons. Similarly there has been little change in the consumption of town gas, though that of coke oven gas has doubled from 1·2 to 2·5 million tons of coal equivalent. The important increase, however, has taken place in the consumption of electricity, which rose from 28·1 million tons of coal equivalent to 50·1 million tons, and of oil, which rose from 17·3 million tons to 35·4 million tons of coal equivalent. Some 44 per cent of the consumption of oil in 1957, however, was for road and air transport.

Hitherto, apart from the growing use of oil, changes in fuel consumption have represented merely a change in methods of using coal since the total consumption of nuclear and hydro-electricity amounted to only 1·7 million tons of coal equivalent in 1957. It is not surprising therefore that gross inland consumption of coal has continued to increase steadily up to 1956, apart from a slight drop in 1952. In 1957, gross inland consumption of coal fell by 5·1 million tons. Of this only 0·7 million tons was due to increased consumption of black oils, the remainder being accounted for by reduced industrial activity and improved efficiency in the usage of coal. A further fall in gross inland consumption of coal seems probable in 1958, but provided industrial expansion can be resumed there is no reason to suppose that the rise in total coal consumption will not be recommenced.

Commonwealth into Conference

The Commonwealth Conference in Canada this month takes place in circumstances somewhat different from those which operated when the Conference was mooted. The external trade position of the United Kingdom is very much stronger and the financial position of India is very much weaker. Australia, New Zealand and Canada are also facing economic difficulties. The American recession has now spent itself and this recession was very much at the forefront of everybody's mind in the second half of last year. The Free Trade Area, which was to have been a major item on the agenda originally, is now much less urgent. The whole concept has run into serious difficulties in its timetable and has been sent down to the experts at OEEC in Paris from the Council of Ministers for further detailed study.

It was expected this spring that the Montreal Conference would be much preoccupied with the need to raise the price of gold. At the end of last year the chronic maldistribution of the world's gold resources was particularly marked. The flow of gold to Western Germany and the United States was still going on and the inability of sterling to finance world trade on attenuated reserves was very apparent. Since then the flow of gold has been reversed and the Sterling Area's gold and dollar reserves are larger than they have been for several years.

The problem of finding capital for underdeveloped areas and the present depressed state of many commodity markets will still be important items on the agenda taking the form of a discussion on the establishment of a new international development organisation for financing capital development. Indeed the agenda itself may be little changed: the emphasis on the different items may be somewhat different.

Engineering in Australia

The Australian engineering industries experienced a very rapid growth between 1945 and 1951. After a temporary fall in demand production again approached capacity level in 1955. Since 1956, however, there has been some divergence in the experience of individual industries: manufacturers of railway rolling stock and of excavating and earthmoving equipment have been operating well below capacity, while industries producing electrical equipment and metal-working machinery have been working close to capacity. Most industries producing durable consumer goods show an expansion of output of the order of 15 per cent between the first quarter of 1957 and the first quarter of 1958. The increase has been most marked in the case of television receivers (100 per cent) and motor vehicles (25 per cent).

The April 1958, issue of the "Survey of Manufacturing Activity in Australia," from which these facts are taken, was published at the end of last month by the Commonwealth Government of Australia, Industries Division, Department of Trade. The survey has been prepared at six-monthly intervals since 1952 but the current issue has been enlarged to include basic statistical and general background information concerning the structure and development of industry, so that current movements can be viewed against long-term trends. It is thought that in this form the survey is likely to become an annual instead of a half-yearly publication.

The current issue contains annual statistics up to and including the year ending 30 June 1957, and in many cases the figures are continued to cover the first eight or nine months of 1957–58. The sections of the report of most interest to the engineering industries are those covering plant, equipment and machinery, and durable consumer goods. The former section covers nine major industries giving employment to more than 60,000, while the latter, which produces goods ranging from household appliances to motor vehicles, employs about 100,000. In addition to statistics of production, trade and employment, the survey lists the principal manufacturers in each field and describes the principal products made.

Openings Down Mexico Way

Mexico is now among the fastest developing countries in the world. Investment in roads, houses, factories is beginning to pay off and living standards generally are rising. Manufacturing is spreading and special facilities are given to firms setting up in some industries. What sort of openings are likely to occur?

The biggest opportunities are in making some products which are now imported. These are all items of which there is already a high level of consumption and for which demand is likely to rise. At present the trend is towards a growing import of capital goods, and away from consumer goods. Such things as cranes, pumps, diesel or industrial valves, electric motors, electric switchgear and ball bearings all of which are imported in substantial quantities and could be increasingly manufactured in the country. Other possibilities among the list of present imports are machines for generating

electric power—they have expressed considerable interest in nuclear reactors—grinding mills, cash registers and office machines, radio and television valves and parts, and cinema projectors. The pattern of manufacturing costs in Mexico is rather different from that in Britain. Labour is considerably cheaper, but productivity is lower. A skilled worker might earn 17*s* 10*d* a day and a foreman 20*s* to 25*s*. Workers tend to be careless with equipment and maintenance costs are higher than here. Cheap natural gas is available, as fuel in Mexico City and elsewhere —but the Mexicans would rather use it as the basis of a chemical industry than burn it.

There is a shortage of executive staff as would be expected in a rapidly expanding economy. Advertising is cheaper than in Britain and considerable use is made of radio and television. The item which is comparatively most expensive is industrial finance. Banks charge 10 to 12 per cent for loans and discounts, which is a heavy item as many sales are on 30, 60 and 90 days credit terms. The Mexican Tax Law is said to be relatively simple and firms operating under the "New and Necessary Industries" Law are largely exempt. Industrial net profits run at about 25 per cent and many companies pay dividends of 12 to 15 per cent after reinvesting part of their net profits. Useful sources of information on opportunities in Mexico are the Commercial Departments of the British Embassy, the Bank of Mexico and, nearer home, the Federation of British Industries.

Railway Activity

Interest in the railway modernisation programme has hitherto centred mainly on the provision of diesel and diesel-electric locomotives. At a Press conference last week, however, the general manager of the London Midland Region dealt with the progress of main-line electrification. He said that work on the conversion to electric traction between Manchester and Crewe was well forward and announced changes in the timing of trains leaving and arriving at Euston Station, due to the slowing down of services which would result from the day and night work on the tracks.

It is hoped that before the end of 1960 electric express services will be running between Manchester and Crewe and by 1963 between Birmingham, Liverpool and Manchester. The training of drivers and motormen will start next month and trials with an electric locomotive are expected to start before the end of the year. Although at this stage any estimate of the cost of electrification to the Midlands and the North could be nothing more than an inspired guess it would probably be between £80 million and £100 million. The engineering work involved is very considerable since, apart from relaying the track and providing the electricity supply, 568 bridges are to be raised while work also has to be done on 350 other bridges and 45 tunnels. From the Eastern Region has come the announcement that Kings Cross station is to be re-built and greatly extended.

The main object of the schemes is to speed services by 10 to 15 per cent with a view to securing an increased share of freight traffic. In their recent application to the Transport Tribunal the British Transport Commission is seeking permission to raise passenger fares by up to 50 per cent. The Commission obtained a large measure of freedom in fixing freight rates a year ago, but since then rates have tended to fall due to the decline in industrial activity and to strong competition from road hauliers. It would appear that the only way to raise freight traffic receipts is to provide substantially improved services, if possible without raising rates. The electrification programme should help in attaining this objective, but it will be some years before the full effects are felt. In the meantime it would appear that rising costs will have to be met by increases in certain passenger fares and Sir Brian Robertson recently hinted that one of the selective fares increases might be the introduction of higher fares for express travel on the American model.

German Railways in the Red

Since the time when the first locomotive to be used on the German railways, "The Eagle," was made at George Stephenson's works, German railways have followed British practice in many ways. From the early 1920's, the railways have been nationalised, first as the Reichsbahn and later as the Bundesbahn, and their Administrative Council, which corresponds to the British Transport Commission, consists of five government officials, five Members of Parliament, five trade unionists, and five industrialists.

In recent years, the Bundesbahn has been losing money—but not because of inefficient management. They received no financial help in the enormous task of repairing war damage and catching up on maintenance arrears and track repairs. Also, the railways bear what are called "political and social" burdens, in the form of pensions to expelled persons and refugees who were formerly employed by the Reichsbahn in what is now East Germany. In 1956, expenditure by the Bundesbahn, at 6,470 million D marks exceeded their income by 354 million marks (about £33 million). Their income increased last year but, although final expenditure figures are not yet available, it is expected that there will again be a deficit. The breakdown of the 1956 income was 3,956 million marks from freight, 1,712 million marks from passenger services, and the remainder from other sources.

German railway equipment has kept pace with modern developments. The 6,000 h.p. series "50" freight locomotives are among the heaviest in the world. Several trains, such as "The Senator," are made up of articulated rolling stock built of lightweight metal. Rail coaches with diesel motors are being widely used for local services, just the same as is being done in Britain. The star turns are the Trans-European Expresses (TEE), with their luxury coachwork, 2,200 h.p. series "200" diesel locomotives, and such amenities as a mobile office with bi-lingual secretaries for German business men. German firms, notably Borsig, Henschel, Kraus, Maffei, Krupp, and MAN, are building up between them a big export business in locomotives and rolling stock. These undertakings, unlike Bundesbahn, are highly profitable.

Comets Over the World

By this time next year, de Havilland Comet 4 airliners will be in commercial operation over a substantial portion of the earth's surface—with BOAC between London-New York and London-Hong Kong-Tokyo; with Aerolineas Argentinas between Buenos Aires-Rio-Trinidad-New York and Buenos Aires-London, via Rio, Dakar, Matric, Paris or Rio, Dakar, Rome, Frankfurt. Later, BOAC will put Comets on the "Kangaroo" route to Australia and on the London-Johannesburg route, and East African Airways will have Comets on their Nairobi-London and Nairobi-Bombay services. Last week a Comet 4 made a proving non-stop flight of 2,200 miles to Cairo in 4½ hours.

In the case of Aerolineas Argentinas, who start operation next May, all their trunk routes will be flown by Comets—and they will have Argentine air crews right from the start. Pilots, flight engineers, navigators, radio operators, mechanics and technicians, dispatchers, pursers and stewardesses are to be trained initially in England. The first four crews to be so trained will then in turn train others in Buenos Aires. Maintenance will be carried out in the workshops of Ezeiza (Buenos Aires international airport), but initially overhaul of the Avon Turbo-jets will be done by Rolls-Royce in England, until the Argentinian personnel are fully trained and have the necessary equipment, by the end of 1960.

Letters to the Editor

TURBO-ALTERNATOR ARRANGEMENT

SIR, In your issue of 1 August, p. 133, there is a description of the plant of the Stork Margarine Works, Purfleet; the heading of the article is "Grease From Edible Oils," suggesting that the main purpose of the article is to give information on this subject. The plant is a large one and contains so much diversified machinery that in the space available it may be unreasonable to expect much detail.

Towards the end of the article reference is made to the power plant. As written in the article, the description of the Brush turbo-alternators is rather misleading and liable to give quite the wrong impression. In the "hand out" given to the Press by the customer, the part describing the turbines was accurate, but in being compressed for your article some of the meaning has been lost. Although the specification called for pass-out turbines, it was possible to make a more efficient arrangement by supplying the steam to the two processes through separate turbines which were connected together so that they could drive one alternator.

The process steam at 170 lb per sq. in is expanded from the initial pressure of 400 lb in a single-stage turbine, the 38 lb pressure process steam is expanded in a nine-stage turbine from the same initial pressure. This arrangement gives a more flexible control than can be obtained with a conventional pass-out turbine, which takes the whole of the steam through the high-pressure end and passes out the amount required at the pass-out point.

In this particular instance, the power developed by the 170 lb per sq. in steam is about 500 kW and the power developed by the steam exhausted at 38 lb pressure is 3,250 kW. To allow for possible variations the combined turbine arrangement is connected to a 4,000 kW alternator. The impression given by your article is that the turbines are separate; there are, in fact, two combined sets.

Yours faithfully,
R. C. MCLEOD.

Brush Electrical Engineering Co., Ltd.
Loughborough.
4 September, 1958.

EARLY SCREW CUTTING

SIR, Judging by the photograph published on p. 198 of your issue of 15 August, George Wailes and Company Limited are to be congratulated on the replica they have made of Maudslay's screw-cutting lathe.

While not wishing to detract from Maudslay's achievement, I feel that your historical note does less than justice to his predecessors. You mention "a fusee engine invented in 1741," which I assume to be a reference to one (of several) described by Thiout in his treatise on horology published in that year in Paris. Fusee engines, however, were in use much earlier. William Derham remarks in the preface to his *Artificial Clockmaker* that "the invention of cutting engines (which was Dr. Hooke's) fusee engines, and others, were never thought of till towards the end of King Charles the Second's reign."

In the second half of the 18th century fusee engines were an article of commerce. An engraving of one copied from one of the Lancashire pattern books is given in Rees's *Cyclopaedia* 1819, Horology Plate XXXVIII, Fig. 2, and another, very similar, to be seen in the Science Museum in London. These examples were for cutting watch fusees and acted by screw and lever. In order that the fusee should rotate between dead centres, it was driven from the screw by a pair of toothed wheels. The effect of changing the ratio must have been well known, but it would not have been a convenient way of varying the pitch. Fusee cutting demanded a steplessly variable pitch and this was provided

Plant and Equipment

TABLET MAKING MACHINE

One of the new items shown by Manesty Machines Limited, Speke, Liverpool 19, at the recent Chemical and Petroleum exhibition was the "DryCota," a double-purpose tabletting machine. In the first part tablets can be made and in the second they can be given an outer coating; either part can be operated independently.

Powder for the core is fed to the left-hand section and is received on a 16-die rotary table. The tablet is then formed by compression. As the table revolves, the tablet is removed by a transfer arm and conveyed to the second table which also has 16 dies. Interlocks stop the machine if a tablet is not picked up by the arm or if a tablet is not deposited in a die. Both tables are driven by variable speed gears.

Powder for the coating is fed to the dies in two stages; first before the core is placed in position and secondly after the core has been centered. The transfer mechanism is such that the tablet is moved by the arm at the same speed as the second table for a sufficient distance to be certain that it is correctly centered in the die and rests on the first injection of coating powder. As in the case of the core, the final tablet is produced by compression in the normal way. The completed tablets are delivered by a chute to the collecting bottle.

When it is desired to coat tablets that have already been made elsewhere, the first section of the machine is cut out and the core tablets fed by a vibratory feeder to the first table at a point subsequent to the compression process. They are then picked up by the transfer arm and conveyed to the second table in the usual way, being there centred on the first injection of coating powder. The second operation, consisting of the injection of the rest of the coating powder and the compression to form the final tablet, then proceeds as before. When it is desired to make tablets without coatings the second portion is cut out, and the tablets collected direct from the first stage.

Four versions of the machine are made; the smallest will produce from 10,500 to 29,700 coated tablets per hour up to $\frac{13}{16}$ in diameter, or up to 59,520 uncoated tablets in the same time. The largest can produce up to 53,820 coated, or 107,640 uncoated, tablets per hour up to a maximum diameter of $\frac{5}{8}$ in. Capsule or other shapes can also be coated.

Core tablets can be made on the left-hand portion of the DryCota and coated on the right, or either section can be operated independently.

Continuing Letters to the Editor

by an adjustable lever connected with the "box" (or nut) upon the leadscrew.

The first use of change wheels seems to have been made prior to 1741, by Henry Hindley of York, 1700–1771, a clockmaker whose skill and inventiveness is as yet unrecognised. In his paper to the Royal Society in 1785, "Observations on the Graduation of Astronomical Instruments" John Smeaton says that he first met Hindley in 1741 and saw his screw-cutting lathe: "though he showed me also this chock (i.e., chuck) lathe, and the method employed to make the threads of the screw equiangular with the axis, that is, to free the screw from what workmen term drunkenness; and also showed me how, by the single screw of his lathe, he could cut, by means of wheel-work, screws of every necessary degree of fineness (and, by taking out a wheel, could cut a left-handed screw of the very same degree of fineness)."

Smeaton in a footnote on this passage says: "A machine for cutting the endless screw of Mr. Ramsden's engine, upon principles exactly similar, is fully and accurately set forth in his Description of his dividing engines above mentioned."

Ramsden's pamphlet was published in 1777 with a triangle bar screw-cutting lathe shown in Plate IV. It was reproduced many times in the following 50 years and, besides, many workmen were trained at Ramsden's establishment so that it is not improbable that it was known to Maudslay. He can hardly have been ignorant of the principles of fusee engines at a time when horology was in the forefront of the mechanical arts.

Maudslay seems to have been the first to produce long lead screws with any pretentions to accuracy and deserves all credit for his judgment in selecting the best means of employing them.

Yours faithfully,
R. J. LAW.

The Old Rectory,
Churchover, Rugby.
5 September, 1958.

TRADING IN THE MIDDLE EAST

SIR, In your issue of 15 August, in your marketing note, "The Arabs Look West," you make reference to the Middle East tour of our Projects Engineer, Mr. L. Johnson. As the result of Mr. Johnson's tour, we are able to confirm the remarks of Mr. Peter R. Watson of Siemens Edison Swan (Export) Limited, which you also report with regard to the potential of the Middle East market for British engineering products.

Two important factors are clear to us, these being rather complementary to each other, namely: (1) would-be exporters to Middle East countries must constantly send technical salesmen to explore the markets, such visits being very much expected and welcomed; (2) manufacturers must give adequate support to their agents, who, by the very nature of the markets, tend to undertake agencies for a rather wide and diverse range of products.

Our major interest in the Middle East is to develop our agents' spares-stocking and after-sales servicing facilities, so that the oil companies and users of plant and equipment can confidently import Dorman-engined equipment, knowing that servicing facilities are available. To facilitate this, we have, over the last three or four years, developed ranges of engines having from two to eight cylinders in which we have introduced the maximum degree of standardisation and parts-interchangeability, thereby making it possible for the current models of our diesel engines to be maintained from the minimum stock of spare parts. In fact, we are now able to offer powers from 20 h.p. to 350 h.p. from two engine ranges, and when our development programme is completed, we shall, from these two ranges, be able to cover up to 700 h.p., which, in effect, means that all the engines within this wide power range will be covered by two stocks of spare parts, having the maximum degree of interchangeability within each of the two ranges.

Yours faithfully,
A. HARRISON.

W. H. Dorman & Co. Ltd.
Stafford.
22 August, 1958.

AN AMERICAN TALKS BACK

SIR, The observations on the United States made by Mr. E. P. Ward fascinated me. I have always been interested to know why the old world has been so slow to see the light. Your articles should help Englishmen to see themselves. That is their great need. I have visited with some of the industry teams who have toured this area, and have read their reports. Like most humans their main aim is to justify their position rather than improve it. The labor member of one joint management labor group who came here spent the evening at the local union quarters speaking against labor saving practices he had seen in our shop during the day. He stated that such practices would not be tolerated in his country, and suggested the local union management was lax in allowing it.

I was glad Mr. Ward was unable to find a materialist formula to explain the American success story. He apparently sensed that it was not materialistic, as his conclusion recognised its "practical," yet "visionary" nature. Actually it is another great paradox like those that seem to be associated with all the great truths. Isn't it strange that a people branded as money worshippers should have every coin inscribed "In God We Trust," and our greatest Shylocks were often our greatest philanthropists? It was surprising he didn't find more people trying to point out the elemental truths of the American system. It is alarming that we should be blind to the principles that have brought us so far so fast.

My understanding of history is that the drive for freedom of worship was the motivating force that brought many early settlers to this country. The framers of our constitutional democratic form of government, inspired by the pioneering spirit of the period, and starting with a clean slate, naturally drew from their Christian faith in writing the constitution. They did not establish an elementary democracy. Democracy based simply on the principle of majority rule soon becomes a tyranny of the worst sort. A democracy only becomes good when it is governed by respect for the God-given right of the individual man. This is another great paradox where the lot of the masses is best served by giving attention to the individual. If only there were a poet to put it in words we could all understand.

One very practical illustration of the fundamental difference in the American and British economic systems is the British acceptance of the cartel or trust practices which would be illegal in this country and punishable by prison sentence. Our constitution makes it clear that it is against the interests of individuals to permit economic monopolies. This difference in economic philosophy which interferes with free competition probably is the underlying cause of the difference in our economic levels.

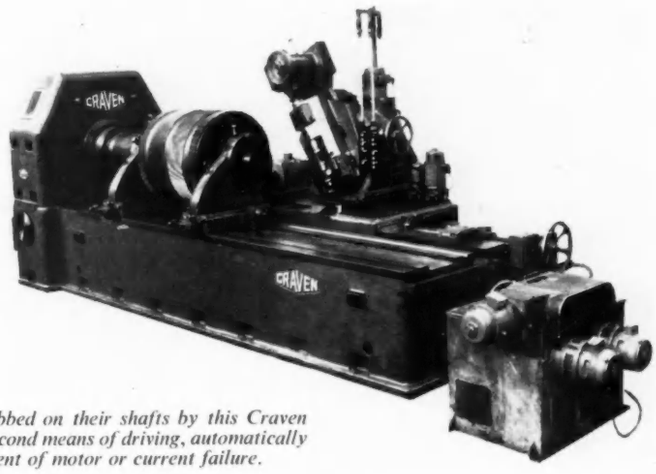
Yours very truly,
ARTHUR W. POPE, JR.

240 N. Porter Avenue,
Waukesha, Wisconsin.
28 August, 1958.

Continuing **Plant and Equipment**

HOBBING TURBINE PINIONS

Turbine pinions up to 3 ft 3 in diameter and 9 ft face width can be hobbed on the special machine illustrated herewith, which has been built by Craven Brothers (Manchester) Limited, Vauxhall Works, Reddish, Stockport, for the Empresa Nacional " Bazan " de C.N.M., S.A., Madrid. The machine is designed to hob pinions constructed integrally with their shafts, and will accept work having an overall length of not more than 12 ft 6 in. It is complementary to a 16 ft vertical type Craven turbine wheel machine supplied to the same customer, and is matched in ratio to produce identical angles on mating gears. Gears up to 2 d.p. can be cut, and the maximum outside diameter and minimum root diameter of the hob are 9 in and 5 in respectively. Maximum hob length is 9 in. The maximum and minimum centre distance between hob and work spindle are 24¼ in and 3½ in enabling pinions from 6 in to 39 in diameter to be cut.



Turbine pinions are hobbed on their shafts by this Craven machine, which has a second means of driving, automatically operated in the event of motor or current failure.

The pinion is mounted horizontally on the two front ways of the machine by means of two capped-type work stays which allow it to rotate on its own journals. Adaptor bushes are provided to suit different pinion shaft diameters. A 20 in diameter cast iron spindle, running in automatically-lubricated bronze bearings and mounted in the headstock on the left-hand end of the machine bed provides the work drive from a 60 in diameter master worm wheel and worm of specially accurate manufacture. A 10 in diameter bore through the spindle allows for extended pinion shafts. Provision is made for fitting a centre adaptor or for location of driving chucks.

Main drive is by a 10 h.p. constant-speed reversing motor through reduction gears and pick-off change gears which give ten hob speeds ranging from 10 to 80 r.p.m. Any number of teeth from 20 to 500 can be cut without special gears, at any speed, tooth angle or feed within the range of the machine, and the feed can be stopped, started or reversed while the machine is running, without interfering with the relative position of the hob and the teeth being cut.

To ensure that there shall be no break in operation once the machine has started hobbing, two main drive motors, coupled in tandem, are fitted. One is for normal alternating current and the other is for direct current. In the event of failure of the a.c. motor, or of the mains supply, the d.c. motor cuts in automatically, taking its current from batteries, until an auxiliary diesel-engined generator can be started to take up the load. Similar precautions have been taken to prevent stoppage of the machine because of lubricating oil supply failure. The gears in the main gearbox and the master worm run in oil, and a constant piped supply of filtered oil is delivered by a motor-driven pump unit to the headstock bearings and to the various bearings and gear trains in the box. A second motor-driven pump unit, operating from the same a.c. supply, is provided as a stand by in case of pump failure, and a third unit, d.c. operated from the auxiliary supply provides against a.c. mains failure. A similar three-pump arrangement supplies cutting lubricant to the hob.

PUSH-BUTTON LOUD-SPEAKER TELEPHONES

The Ringmaster loudspeaking telephone system being distributed in this country by the Office Equipment Division of E M I Sales and Service Limited, Hayes, Middlesex, introduces a push-button dial panel on a loudspeaking system capable of 999 extensions. Two types of operation are available: (1) " Simplex " where the conversation is controlled by the person initiating the call—the person receiving the call does not touch his intrument and has only to answer. This control is operated by the " T " button (press to speak and release to listen); and (2) " Duplex " operation which eliminates the speech/listen function of the " T " button. After the connection has been made the conversation may be held freely at both ends without touching either instrument. This " Duplex " version provides a high speed electronic alternation without clipping either conversation. In addition, all " Duplex " operated units are equipped with the " Simplex " T button, in order that manual operation may be used when it is desirable to control a conversation, or when an extreme disparity in noise levels would tend to unbalance the electronic control of the amplifiers.

There are basically two systems with either group or co-ordinate selectors. The maximum build-up on the former is 50 units, on the latter 999. Both systems are fully inter-communicating, but whereas the amplifiers are automatically selected in the latter, in the former they are allocated one to each group. Wiring of either system is straightforward—co-ordinate selectors calling for 2½ pairs to each telephone and 7½ pairs in parallel. For group systems 11 pairs in parallel are employed, plus one leader to each telephone. The telephone units for group or co-ordinate selector systems are identical in appearance and operation.

The Ringmaster telephone unit employs a push-button panel instead of a dial for the numerical combinations. The normal unit as supplied is of the loudspeaking type but can also be fitted with a conventional hand set which, when lifted, automatically disconnects the loudspeaker. In addition to the numbered buttons, the unit is equipped with a T button, already mentioned, which performs the dual function of " Simplex " control and energising the amplifier. There is also an " X " button which is used for clearing the connection on termination of the conversation or for refusing an inconvenient call. Two lamps are located on the unit—the red lamp indicating when all channels are engaged and the green, that the unit is being called. In addition, there is a short call signal.

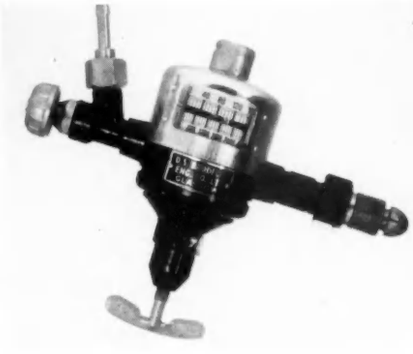
Auxiliary (or sub) units are available with various sizes of loudspeakers. They are not normally able to initiate calls, but where it is necessary it can be arranged for auxiliary units to initiate calls to one or two other units. In common with the standard units, the output of these auxiliaries is approximately ½ watt.

It is possible to connect all stations in a system for general announcements or paging. In other words, pressing the appropriate code will call in the entire organisation. This is made possible by parallelling all speakers and employing a booster amplifier. Additional wiring has to be employed in the form of an extra pair to each telephone unit. The " calling " connection is automatically cancelled on pressing the X button. Alternatively, there is a visual system which employs a small indicator panel of five red lamps from which it is possible to obtain patterns for 50 different people.

Blocking switches are available from all units which will either isolate the unit completely or leave the warning tone and indicator light. This latter allows a person to observe that someone is trying to call him and thus offers the opportunity of accepting the call.

Secretary facilities are available for interception or diversion. In the former case a switch is installed in the secretary's telephone unit which when engaged, will allow her to intercept all calls to her superior. The diversion switch is fitted as an alternative to the latter and allows an executive to switch all incoming calls to his secretary, when not wishing to be disturbed.

GAS REGULATOR



When using gas from cylinders it is usual to fit a regulator to control the downstream pressure and flow. A new example is now being made by the D. S. Baddeley Engineering Company Limited, 43/45 York Street, Glasgow, C.2, and is shown in the illustration. In addition to the regulating diaphragm the device contains pressure gauges on both the high and low-pressure sides, contents gauge, safety valve, and sealing valve. It is particularly claimed that the regulators avoid the risks of damage that are inherent in the use of normal pressure gauges. The " Recorde " regulators are less than 4 lb in weight and are available for all types of gas cylinder.

Pressure and contents gauges are embodied in the gas regulator.

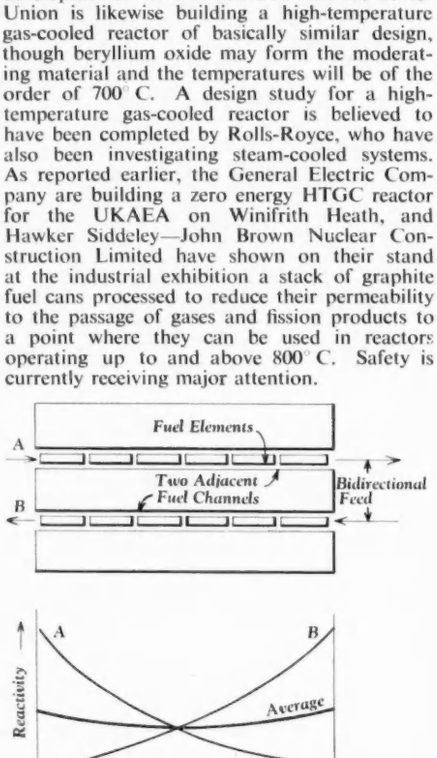
Atomic Review

Selection

THE following items are a somewhat personal selection from the papers presented at the Second International Conference on the Peaceful Uses of Atomic Energy.

Fission

The movement towards higher temperatures in reactors generally has been confirmed by many papers, but in particular is this true of the gas-cooled system. A 10 MW (heat) design study for a high-temperature (800° C) gas-cooled reactor, which may be built in Britain in association with OEEC, is described in an article beginning on page 336. The use of uranium oxide (UO_2) fuel is playing a part in this and parallel developments. It is understood that the Soviet Union is likewise building a high-temperature gas-cooled reactor of basically similar design, though beryllium oxide may form the moderating material and the temperatures will be of the order of 700° C. A design study for a high-temperature gas-cooled reactor is believed to have been completed by Rolls-Royce, who have also been investigating steam-cooled systems. As reported earlier, the General Electric Company are building a zero energy HTGC reactor for the UKAEA on Winifrith Heath, and Hawker Siddeley—John Brown Nuclear Construction Limited have shown on their stand at the industrial exhibition a stack of graphite fuel cans processed to reduce their permeability to the passage of gases and fission products to a point where they can be used in reactors operating up to and above 800° C. Safety is currently receiving major attention.



Bi-directional fuelling to maintain reactivity.

United States reports show that organic moderated and boiling-water reactors may not suffer from some of the disadvantages that were anticipated. Thus the Organic Moderated Reactor Experiment (OMRE) has demonstrated that decomposition of the moderator is not such as to cause fouling of the fuel elements or heat exchangers; indeed as the percentage of high boiling polymers increases the rate at which the terphenyl decomposes is reduced. It was stated that with a high-polymer content of 40 per cent, there was only a slight reduction in heat transfer. Cost of replacing the degraded moderator adds only one mill per kWh to the total cost of power. As previously reported in Atomic Review, the Experimental Boiling Water Reactor (EBWR) has proved stable when operating at three times its design power level.

In Canada, and elsewhere, the use of heavy-water as a moderator appears to be leading towards cheap power from natural-uranium reactors. In addition, with a relatively inexpensive sintered oxide, burn-ups as high as 8,000 to 10,000 MW days per ton of uranium have been shown to be possible, so that fuel costs amount to less than one mill per kWh without credit for plutonium. Total fuel costs might then be 1½ mills per kWh including inventory and processing, giving an overall power cost of 5 mills per kWh. Fall in reactivity as irradiation proceeds may restrict the actual burn-up, but it seems probable that by employing bi-directional fuelling, whereby fuel in alternate horizontal channels is gradually fed through in opposite directions, as illustrated on the left below, adequate reactivity may be maintained and burn-up may still be as much as 8,000 MW days per ton. Bi-directional fuelling is to be used in the Canadian 20 MW power reactor NPD-2.

Although no new power reactor has been put into operation in the Soviet Union since the 5 MW pressurised-water cooled graphite-moderated plant described at the 1955 Conference, development and research work has clearly been carried out on a generous scale. In particular, results from zero-energy fast reactors have evidently been such as to permit the construction of two commercial fast-reactor power stations, one of 50 and the other of 250 MW capacity. In a 400 MW station now building in the Urals, which is a development of the original 5 MW plant, steam will be superheated by passing through a second region in the grapnite-moderated core; the station will have four 100 MW (electricity) reactors. Two 420 MW stations, each with two pressurised-water reactors, are under construction, one in the Voronezh district, the other in the Urals, while a 7 MW mobile power reactor of pressurised-water design is said to be nearing completion. A 50 MW boiling-water reactor is being built on the Volga in the Ulyanovsk district. A 35 MW (heat) boiling homogeneous reactor in which a uranium salt is dissolved in heavy water, and a 50 MW (electrical) sodium-cooled reactor are also under construction in the Volga area. A large centre has been established on the Volga, where various prototype power reactors are to be located. It is reported that a 600 MW station is also under construction in Siberia.

Czechoslovakia is building a 150 MW station, using natural-uranium fuel, heavy-water moderator, and high-pressure gas cooling.

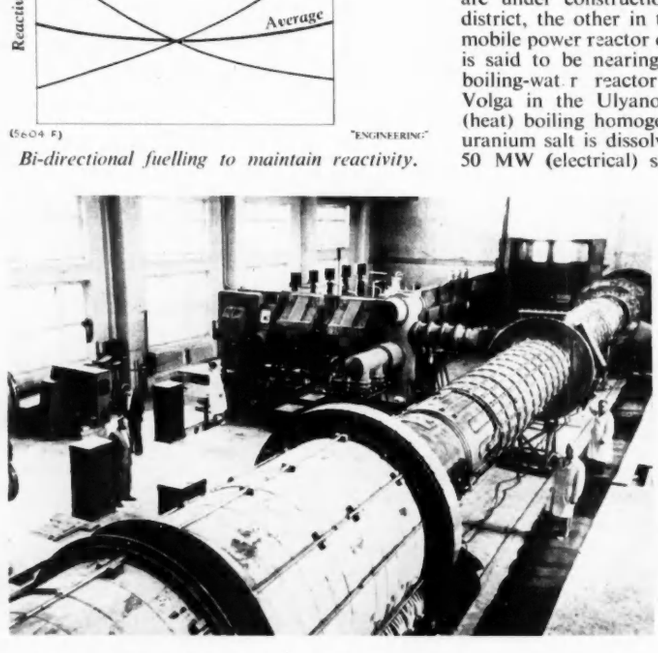
Fusion

Soviet research on thermonuclear reactions does not appear to have proceeded at the same pace, though many small-scale devices have been operated. A large straight-tube device, OGRA (shown below) and a toroidal pinch apparatus ALPHA, similar to ZETA, have been built, but no results are as yet available. A thermonuclear device has two functions: it must both heat and contain the gaseous fuel, which may be deuterium or a mixture of deuterium and tritium. Containment is usually effected magnetically, and heating may occur during, before, or after the establishment of the containing field. Devices in which the ionised gas or plasma is contained by external fields independent of the heating currents are known as magnetic traps. Ideally the containing process should be stable, and a steady-state device is likely to be more successful than a dynamic or fast pulse apparatus.

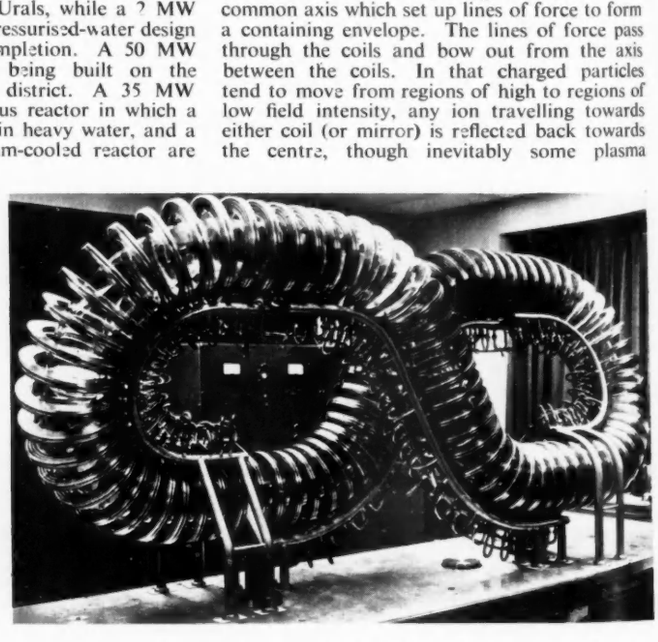
United States research on thermonuclear reactions and plasma physics is impressive. Numerous devices have been operated and valuable results obtained. Four basic approaches can be discerned in American thermonuclear machines, though these are sometimes found in combination, possibly with additional means for injecting pre-heated or accelerated plasma. Previous references to these devices appeared in Atomic Review on 16 May, 18 July and 8 August.

The first, known as pinch effect, which has also been adopted by the British, may be operated in straight tubes as in MAGGI at AWRE, Aldermaston, or in toroidal tubes like ZETA and the AEI device SCEPTRE. American pinch machines include the straight COLUMBUS and torus PERHAPSATRON series. A stable cylindrical sheet plasma may be obtained in devices like the American TRIAX, which comprises two concentric cylinders. Pinch-effect machines are those in which the plasma is contained by the field of the heating current, and sometimes in addition by the electromagnetic reflecting action of the conducting walls of the vessel.

The second approach involves a mirror machine—described by Sir George Thomson as a beautiful idea—comprising two coils on a common axis which set up lines of force to form a containing envelope. The lines of force pass through the coils and bow out from the axis between the coils. In that charged particles tend to move from regions of high to regions of low field intensity, any ion travelling towards either coil (or mirror) is reflected back towards the centre, though inevitably some plasma



A Soviet thermonuclear device, OGRA, apparently a mirror machine.



Demonstration figure-of-eight version of the United States stellarator.

escapes. Heating may be effected by adiabatic magnetic pumping, whereby the field is alternately intensified and slackened. One system comprises a series of mirror machines with increasingly constricted fields so that the plasma is squeezed smaller and smaller as it is forced by a uni-directional magnetic pumping action from one machine to the next.

The third approach is the stellarator, a group of devices in which the plasma is likewise contained by externally applied fields, though as in toroidal pinch machines the plasma is in a closed circuit. Unlike the pinch machines, however, the stellarator employs a separate and comparatively weak heating current, which contributes scarcely at all to plasma containment. The tendency of the plasma to drift towards the walls of the torus is restricted by effectively twisting the plasma, either by means of secondary coils or by twisting the torus itself to form a figure of eight, as in the model shown on page 334. This effect may be understood by considering a strip of paper which is first twisted through 180° and then stuck to form a closed loop: the strip has then only one side. Similarly a layer of plasma has only a single surface and by a sort of symmetry (or more accurately topological) effect is prevented from drifting. A variation of the stellarator principle is provided by ASTRON, in which containment is afforded by a long rotating cylindrical layer of relativistic electrons (the E layer).

The fourth method may be called the rotating plasma system. The plasma is contained in a toroidal chamber and under the action of a radial electric field established between the inner and outer walls of the torus is forced to travel round the chamber, behaving like the rotating part of a homopolar electric motor. However, the path of any particular ion is a series of trochoids or loops, and inasmuch as these loops are out of phase with each other, the motion will be effectively random so that thermonuclear reactions will occur. IXION is a combination of this approach and the mirror machine.

Ion velocity may be increased when the gas is already trapped in the magnetic field or before it enters the apparatus, as in the Oak Ridge Laboratory's Direct Current Experiment (DCX). Injected deuterium ions are dissociated by an arc along the axis of a mirror device. On dissociation the ions are trapped in a closed orbit near the axis of the machine.

Several important results were disclosed during discussions. There were two criteria by which the origin of neutrons could be judged: they were unlikely to be the result of thermonuclear reactions unless (*a*) the field pressure corresponded to the extent of emission, and (*b*) the neutrons were anisotropic in their motion. Only SCYLLA, an American machine combining the mirror principle with magnetic pumping, had produced neutrons satisfying both conditions.

A more important result was that there was a "crevasse" in the operation of pinch machines whereby a considerable proportion of the energy introduced was lost in some way; in other words, neutron emission was considerably smaller than would be expected from the input of energy. It was said that if this effect were explained in one way it might be circumvented, but if in another then the pinch machine might be eliminated from the running in the race for thermonuclear power.

It was also apparent that small pinch devices were unlikely to be successful, since to be reasonably efficient a fast (or dynamic or unstabilised) pinch machine would require a rate of energy input equivalent to an explosion of about 10 tons of TNT, which would with present engineering techniques be intolerable.

In addition, the Russians had employed conventional high explosives to initiate thermonuclear reactions, with some success, but these experiments had now been discontinued. Conversely, the Americans were planning to contain thermonuclear explosions by detonating them underground. Such explosions might be used for mining, large-scale excavation, the release of oil deposits and even for power production.

Companies in the News

Names and Games

Two members of the BSA group change their names. The plastics division of Metal and Plastics Compacts Limited, motor cycle accessory manufacturers, will be trading as Motoplas Company and the metals division as Metals and Plastic Components. This is an acknowledgement of the fact that the plastics and metals divisions of MPC had become separate organisations. MPC was set up by BSA in 1946 to investigate powder metallurgy and manipulation and moulding in the plastics field.

A similar operation has been carried out by Brayshaw Furnaces and Tools Limited, whose industrial furnaces and engineers' tools divisions will trade as separate companies—Brayshaw Furnaces Limited and Brayshaw Tools Limited. This took place on 1 August, in the Diamond Jubilee year of the original company.

Another change of name by a subsidiary: Jowett Cars Limited who are members of Blackburn Aircraft Group, have been changed to Jowett Engineering Limited "to facilitate future activities." The company point out that this will in no way affect their arrangements for supplying spare parts for Jowett vehicles and reconditioning customer's cars.

Richard Costain announced that they have agreed to acquire 115,000 ordinary shares of £1 each in Costain (West Africa) Limited, from John Holt and Company (Liverpool) Limited. This gives Costain the controlling interest and is in accordance with their policy of operating in overseas contracting interest through subsidiary companies with local shareholding.

Beyer Peacock continue to expand their manufacturing interest, in accordance with their policy of diversification. Their latest acquisition is Air Control Installations of Ruislip, Middlesex, who manufacture a wide range of air treatment equipment and will continue to do so.

Instrument Pointers

George Kent Limited have experienced a small decrease in the volume of orders for their instruments and meters. Their chairman, Commander P. W. Kent, commented that the company had done very well to suffer no more than a 7 per cent reduction in profit before tax and a 16 per cent drop in turnover. Apart from the demand for motor vehicles steering gears, which continued to rise, orders have generally been less. Much of the company's instrument and meter production is normally required for capital schemes which "have been slowed down in the prevailing restrictive atmosphere" thereby causing a fall in outstanding orders. Commander Kent said that there were, in mid-1958, "signs that the trend is about to rise again" but warned shareholders to expect a decrease this year in the volume of output which has been rising steadily for the past four years.

Another instrument company, Honeywell Controls Limited, have recently held the official opening of their new head office building in Greenford, Middlesex. Mr. Harold Sweatt, chairman of the Honeywell organisation, came over from Minneapolis for the ceremony and told the staff that he considered the British company's rate of growth as "phenomenal." Although they started only eight years ago they are among the largest instrument makers in the United Kingdom, with a factory of 166,000 sq. ft, and operating from ten branch offices.

Theirs to Reason Why

The Cohen 600 Group ended their financial year on 31 March with a turnover of £32·7 million and a trading profit of £1·8 million. This was over £½ million lower than the previous year though turnover was slightly higher. There was a fall either in output or in orders received, for almost every company in the group. The raw materials division experienced a severe fall in demand for scrap and profit margins were reduced "to an unwelcome extent." The machinery division maintained their turnover very well, but the trend of orders is not very satisfactory. Sales of mobile cranes made by K & L Steelfounders—the Jones Crane—increased "despite fierce competition," but orders are falling.

The company's difficulty in maintaining export sales has contributed most to the lower turnover. There were also less orders for T. C. Jones and Company, the group's constructional engineering company. The Colchester Lathe Company were operating at two-thirds capacity towards the end of the year, despite the fact that 17 per cent more lathes were produced than during the previous year. Again the main contributing factor to the decline was a fall in exports—"a sudden drying up" of the American market and a substantial decrease in orders from Canada. Political or exchange difficulties have proved hindrances in other valuable overseas markets. On the other hand, Gamet Products Limited, one of the newer acquisitions of the group, have a new works under construction "for the purpose of doubling production facilities."

Mr. Cyril Cohen foresees no sudden return into top gear. "A realistic assessment of the present trends," he said, "requires that we budget for smaller profits." Many engineering manufacturers will agree with him, for the next six months at the very least.

BEA Loosing Height

British European Airways made a trading profit of £1 million in their past financial year but are currently struggling to make ends meet and may end the year in the red. Their chairman, Lord Douglas of Kirtleside gave the same reason for this change of fortune as his colleague, Sir Gerald D'Erlanger, gave a few weeks ago in respect of BOAC. Traffic has failed to rise as fast as expected and the heavy capital expenditure continually being incurred can only be sustained on a sharply rising turnover. The marked fall in the growth of traffic has been due partly to the world recession and also, on domestic routes, to the effects of the high Bank Rate. Lord Douglas suggests that the rate of re-equipment has been too high and is asking for a mutual agreement among airlines to slow it down. The report also urges a simplification of present tourist class standards to allow for fare reductions and foresees the need for a differential fare (at least in the initial period) for jet aircraft.

The Corporation carried 2·8 million passengers, 24,555 tons of freight and 7,465 tons of mail during the year. Capacity was raised by 15 per cent and receipts increased by 18 per cent. The passenger load factor on international routes, nearly 68 per cent, was the highest of any major intra-European operator and their share of the normal scheduled traffic on the routes they serve rose from 57 to 58 per cent. On the other hand, they lost business to independent operators on the cross-Channel routes "mainly because of large increases in independent operators' inclusive tour and car ferry services."

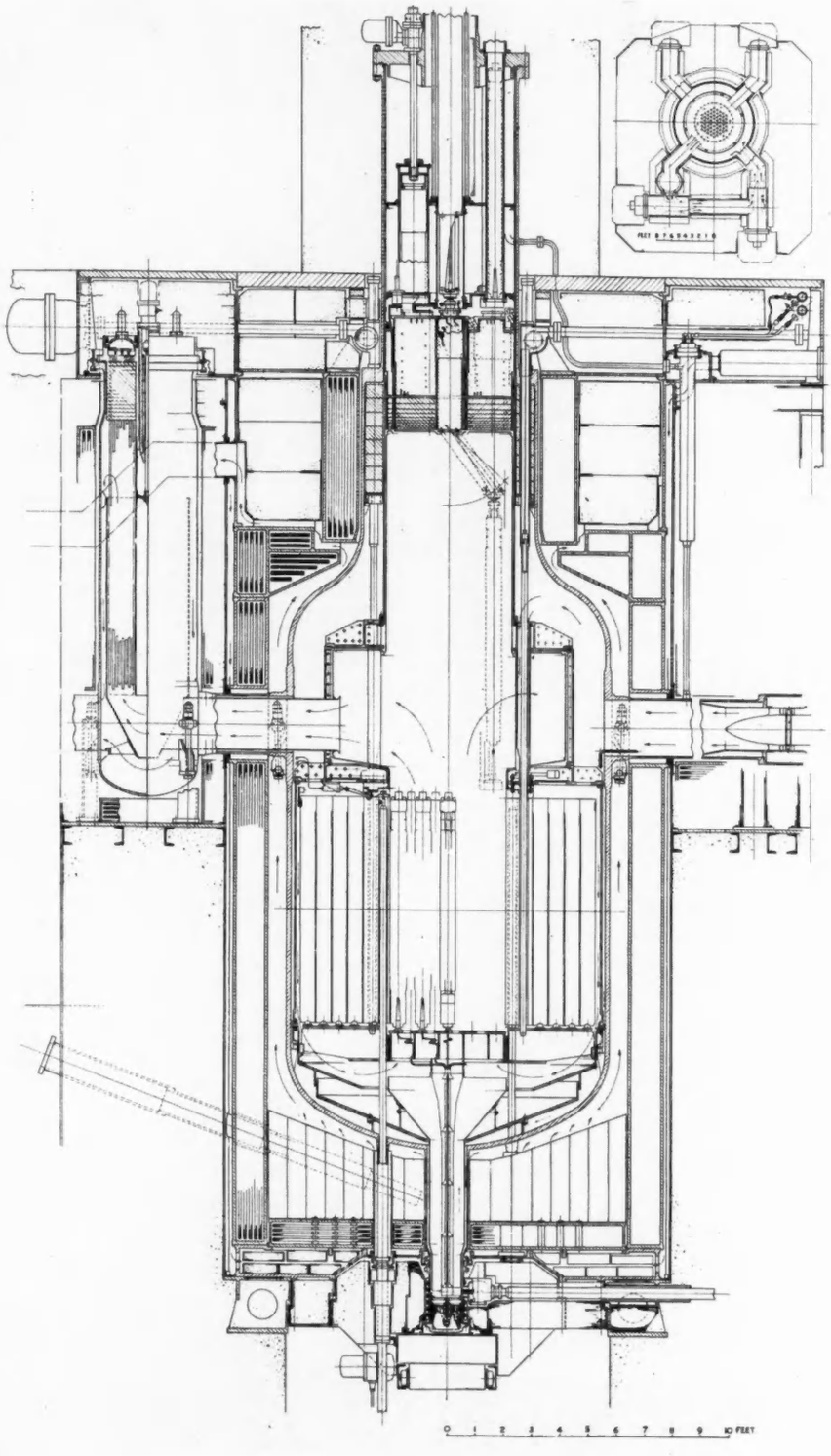
The fall in holiday traffic was most marked. In June last year, more than 72 per cent of the seats in the Corporation's aircraft were sold: in June this year the proportion had fallen below 62 per cent. Lord Douglas's statement suggests that many more passengers will be needed to enable the very costly jets to pay for themselves on short routes, and that many of the frills will have to be removed if the popularity of air travel is to continue its upward climb.

Special Article

BRITISH REACTOR

Achieving High Temperatures in a Gas-Cooled System

Britain has chosen to concentrate her major nuclear effort on reactors with gas cooling. If this approach is to be successful, the gas-cooled system must show a marked capacity for evolution, and already there is evidence that this is so. The nature and extent of this potential has been indicated by one of the papers presented at the Second International Conference on the Peaceful Uses of Atomic Energy. "The Possibilities of Achieving High Temperatures in a Gas Cooled Reactor" (P 314), by L. R. Shepherd, R. A. U. Huddle, L. A. Husain, G. E. Lockett, F. Sterry and D. V. Wordsworth, all of the Atomic Energy Research Establishment, Harwell, is published here in abridged form. A previous paper contributed to ENGINEERING by Dr. P. Fortescue and Mr. D. V. Wordsworth on the design of gas turbines for use in conjunction with high-temperature gas-cooled reactors appeared in our issue of 28 February, this year (vol. 185, page 284, 1958).



EXPERIENCE over the first year of operation of the prototype gas-cooled natural-uranium power reactors, in the United Kingdom, has confirmed that these systems are likely to be competitive with conventional power plants. While the cost of electricity generated by coal and oil is expected to increase, that produced in developments of the Calder type power station should show a downward trend. But the future of these reactors will not be determined by their ability to compete favourably with chemical power sources, but rather by their merits with respect to other types of nuclear power plant of advanced design.

CRITERIA FOR SUCCESSORS

Choice of a successor to the gas-cooled natural-uranium reactor must be guided by considering what features would be desirable. Thus (1) the plant should be reasonably compact; (2) its coolant outlet temperature should be sufficient to operate the most modern steam turbine generating sets, that is, with steam temperatures up to 600° C; it should be high enough, preferably, to operate a fairly efficient gas-turbine cycle; (3) accepting the fact that high-enrichment fuel might have to be used, the system should incorporate a fertile material and should possess a high conversion or breeding ratio; and (4) the fuel elements should be capable of withstanding a considerable burn-up, allowing them to remain in the reactor for a long time.

If operating temperatures are to be high, water or organic liquids cannot be used as coolants, leaving liquid metals, fused salts and gases as possible candidates. Liquid metals present major problems of corrosion and compatibility; and fused salts have high melting points. Gases, on the other hand, retain the same state from normal to very high temperatures; and, particularly in the case of noble gases, are only mildly corrosive compared with liquid metals. Though it is argued that liquids are far superior to gases as heat-transfer agents, the circulation of gaseous coolants need not involve any loss of energy, and if refractory materials are used in the reactor core, high temperature differences may be tolerated, so that heat may be extracted at a very high rate from a small core. Reactors of this kind may therefore be compact, and suitable for use in propulsion plants.

GAS TURBINES AND STEAM CYCLES

It was thought that the minimum coolant outlet temperature necessary to meet the conditions of modern steam generating equipment, would be in excess of 650° C. The possibility of gas-turbine applications suggests that a still higher figure might be desirable and current thoughts are focused upon a coolant outlet temperature of 750° C. An interesting variant which might be used to generate electrical power at high efficiency would involve a steam cycle, but would employ, also, a free running

Fig. 1 (right) Arrangement of free-running turbo-circulator system for use in conjunction with high-temperature gas-cooled reactor.

Fig. 2 (left) Vertical section of a proposed 10 MW (heat) high-temperature gas-cooled reactor experiment.

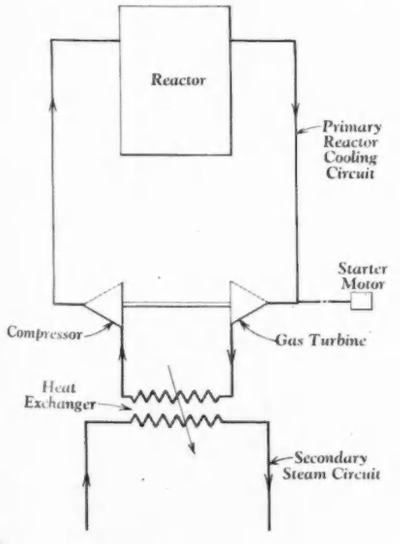
OF THE FUTURE

gas-turbine driven circulator. This system which was proposed by Fortescue and Middleton is illustrated in Fig. 1. Briefly it consists of a gas turbine, utilising the reactor coolant as a working fluid, which produces shaft power to drive the compressor circulating the coolant through the reactor. Both turbine and compressor may be totally enclosed within the primary circuit. Ideally, there is no loss of power in this circuit, as would be the case if the compressor were driven by an external electric motor. The pumping power is obtained at the expense of a certain degree of temperature degradation between the reactor outlet and the inlet to the heat exchanger. It is estimated that a reactor outlet temperature of 750° C would provide an adequate margin for this temperature degradation, while still leaving a sufficient temperature at the heat exchanger to permit the generation of steam at 550° C. An overall thermal efficiency approaching 40 per cent should be attainable in a system of this kind.

FUEL DISPERSED IN MODERATOR

The attainment of an outlet gas temperature of 750° C from the reactor suggests that the maximum fuel surface temperatures may be in the region of 1,000° C or more. It is a first requirement, therefore, that the fuel elements should be capable of withstanding this high surface temperature and that they should be compatible with the selected coolant under such conditions. The question of suitable forms that the fuel and cladding material might take arises immediately. This, however, requires additional considerations to be taken into account, particularly with respect to the manner in which fissile, fertile and moderating material should be distributed through the reactor. All these factors have to be taken together in arriving at a logical optimum design.

One possibility which suggests itself immediately is that of retaining the conventional heterogeneous design of reactor in which canned fuel elements are loaded in parallel channels through a stacked moderator. The implication of high fuel-element surface temperatures on this design would be that the cladding would have to be made from more refractory materials than have been used in the past and, moreover, that the fuel itself would need to be in the form of oxide or carbide rather than metal. Stainless steel or nickel-chromium alloy cans would still be usable at 1,000° C, though one might wish to go to even more refractory metals provided that all compatibility problems could be solved.



However, it may be remarked that the employment of suitable metallic cans would lead inevitably to a serious neutron loss and enriched fuel elements would be essential.

The need for employing enriched fuel has been accepted at the outset of the studies at AERE. In fact, present thoughts turn around the use of thorium as a fertile material with almost pure uranium 235 as the initial fissile component. A practical power system based upon this combination of fuel and fertile material might consist of 1 atom of uranium 235 (or uranium 233) to 20 atoms of thorium 232. This high fuel concentration has led away from the completely heterogeneous reactor concept to one in which the fuel elements incorporate moderating material as a diluent for the fertile and fissile components. Dilution in this manner leads to two advantages. In the first place, it makes it easier to increase the total heat transfer surface area so that high heat ratings, both with respect to unit mass of invested fissile material and with respect to unit volume of reactor core, are made possible. Secondly, as a result of dilution it should be possible to accommodate a greater amount of fission products without seriously damaging the fuel elements.

From the standpoint of utilising the fissile material in an economic manner it is considered that the rating should not be less than 1 MW per kg of the fissile component. Considerations of compactness of the reactor suggest that it should be designed to give a heat output density of about 10 MW per litre of core or more. Investigations have shown that this power density may be attained with helium cooling under pressures of about 10 atmospheres, with moderate circulation speeds and surface heat fluxes not much in excess of 10 watts per square centimetre.

COOLANTS AND MODERATORS

The studies at AERE on high-temperature gas-cooled systems have been carried out with the main emphasis on economic power reactors. As a result, good neutron economy has been considered to be one of the most important features. A gaseous coolant, even a fairly strong neutron absorber such as nitrogen under some 10 atmospheres pressure, does not account for more than a fraction of a per cent of the total neutrons absorbed and, therefore, has no material influence on the neutron economy. On the other hand, to keep surface heat fluxes as low as 10 watts per sq. cm while maintaining a reasonable fuel rating, that is, 1 MW per kg of fissile material, the problem of neutron absorption in cladding materials becomes very important. If, for example, stainless-steel cladding 0·01 cm thick were used, approximately 15 neutrons per hundred fissions would be lost by absorption in that material.

Neutron economy arguments, of course, do not rule out the use of zirconium as a cladding metal, and this was seriously contemplated in the initial stages of the investigations. However, problems of high temperature compatibility, for example, between zirconium and graphite, weigh strongly against the use of this metal and the system would be restricted entirely to a pure noble gas as coolant. In the circumstances, it was decided that an attempt should be made to design a system which had no metallic cladding and in which the moderator, fissile and fertile materials, alone, constituted the solid matter in the core. From the standpoint of neutron conservation this is an excellent arrangement, but it has given rise to several novel and difficult problems, of which fission product containment is one of the more important.

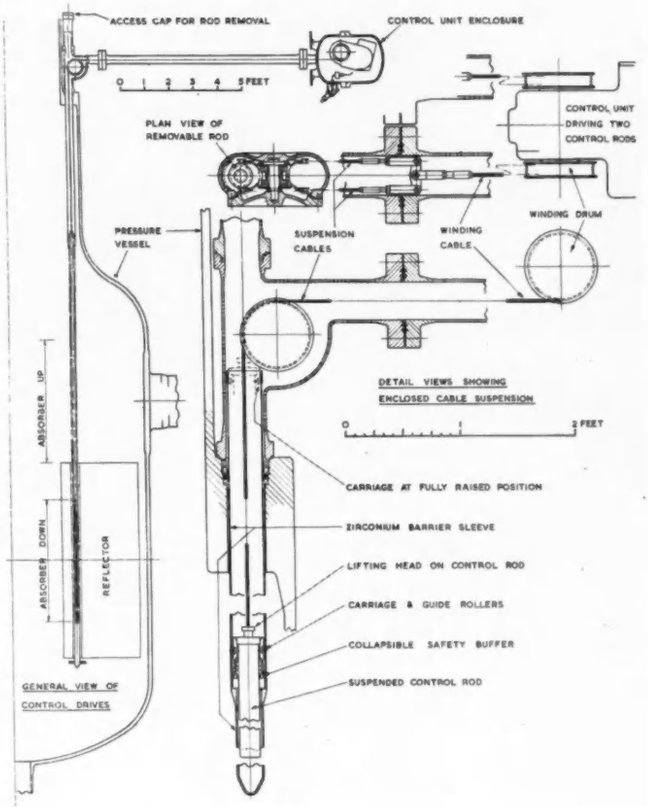


Fig. 3 General view and details of control-rod drives.

The choice of moderator for high temperature gas-cooled reactors lies mainly between graphite and beryllia. Both of these are being considered in present studies, though rather more attention, initially, is being given to graphite than to the oxide. So far as thermal and mechanical properties are concerned, graphite is excellent at high temperatures. Its ability to withstand thermal shock and large temperature gradients is particularly useful. However, its chemical properties leave much to be desired and serious problems arise in connection with the lack of compatibility of unprotected graphite with coolant gases, especially if the latter are oxidising or contain oxidising impurities. Beryllia on the other hand, while its thermal properties are undoubtedly inferior to graphite, is far superior chemically, and is compatible with a very wide range of coolants at high temperatures. As a moderator, beryllia is superior to graphite and its use in a reactor incorporating a fertile material should generally result in the attainment of high conversion or breeding ratios.

Since the use of graphite in the first high-temperature reactor experiment is proposed, the choice of a coolant is severely restricted. Chemical considerations have narrowed the

Continuing British Reactor of the Future

selection down to helium as a first choice with nitrogen as a possible alternative. The greatest disadvantage of helium is connected with its availability, which is such as to throw doubts on the feasibility of employing it in an extensive power programme. On thermodynamic grounds, it is not as good as carbon dioxide but it is better than nitrogen. Its main drawback, thermodynamically, is that being monatomic, it has a low molar specific heat.

Helium, being a noble gas, does not by itself present any compatibility problem. It has been suggested that, in the presence of radiation, reactions involving helium ions might take place. However, in the reactors under investigation it is unlikely that the density of ions would be sufficient to produce an appreciable effect. The question of compatibility with helium as a coolant arises, therefore, only in so far as impurities are present. As the systems considered have graphite surfaces at 1,000° C exposed to coolant, the problem of corrosion by oxidising impurities, for example oxygen or carbon dioxide, is very serious. Present evidence suggests that the concentration of free oxygen in these systems would need to be kept below one part per million in order to keep the rate of attack to a reasonable level.

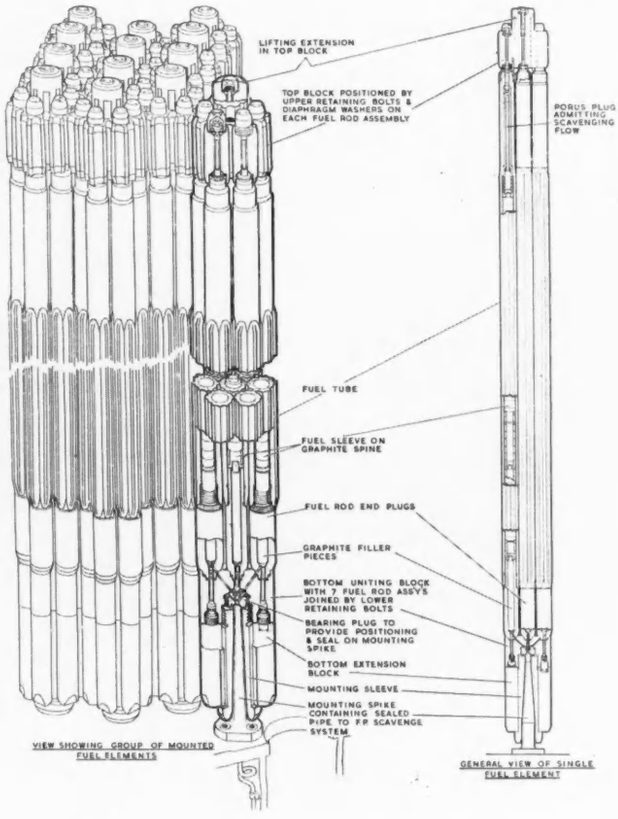

LIFTING EXTENSION IN TOP BLOCK
TOP BLOCK POSITIONED BY UPPER RETAINING BOLTS & DIAPHRAGM WASHERS ON EACH FUEL ROD ASSEMBLY
POROUS PLUG ADMITTING SCAVENGING FLOW
FUEL TUBE
FUEL SLEEVE ON GRAPHITE SPINE
FUEL ROD END PLUGS
GRAPHITE FILLER PIECES
BOTTOM UNITING BLOCK WITH 7 FUEL ROD ASSYS JOINED BY LOWER RETAINING BOLTS
BEARING PLUG TO PROVIDE POSITIONING & SEAL ON MOUNTING SPIKE
BOTTOM EXTENSION BLOCK
MOUNTING SLEEVE
MOUNTING SPIKE CONTAINING SEALED PIPE TO F.P. SCAVENGE SYSTEM
VIEW SHOWING GROUP OF MOUNTED FUEL ELEMENTS
GENERAL VIEW OF SINGLE FUEL ELEMENT

Fig. 4 *Fuel elements for high-temperature gas-cooled reactor experiment.*

BREEDING AND HOMOGENEITY

Current ideas on high-temperature gas-cooled reactors are based on the use of thorium as the fertile material. The uranium 233—thorium 232 breeding cycle is much more favourable at low neutron energies than the plutonium 239—uranium 238 cycle and it is considered that breeding ratios in the region of unity should be attainable, at least in the case of beryllia moderated systems. Of course, it is assumed that a large power programme would call for the use of uranium 235, to seed the reactors, since the amount of uranium 233 initially available would almost certainly be inadequate.

The extent to which the fissile and fertile materials are incorporated in the moderator is a matter involving several factors. A completely homogeneous core has the advantage, from the stability aspect, that the fission energy release takes place directly in the moderator and the neutron temperature coefficient is prompt. On the other hand, in this arrangement the temperature of the moderator is high and a large amount of excess reactivity has to be built into the system to compensate for the rise in neutron temperature. In the more conventional heterogeneous system, by contrast, the moderator is relatively cool, since it receives most of its heat only by indirect means such as conduction and convection.

In the homogeneous system the whole of the core moderator, with the incorporated fissile and fertile materials, is fabricated into fuel elements. This arrangement, as indicated previously, makes it possible to obtain a very large area of heat transfer surface for a given amount of fissile material. However, starting with this form of core construction, there are some advantages to be obtained from adopting a certain degree of inhomogeneity within the elements themselves. One possible arrangement would involve having a layer of inert moderator (that is, containing no fissile or fertile material), around the outside of the fuel element effectively forming a can. This procedure has been adopted in studies at AERE, since it is considered that every attempt should be made to keep the fission-product contamination of the primary circuit to a minimum.

The problem of containment of fission products assumes major importance in systems of the type being considered for high-temperature gas cooling. The complete absence of any cladding material results in a situation where fission products emitted by the fuel can pass straight into the primary coolant. This process is accentuated by the high fuel-element temperatures, which may be in the region of 1,500° C in the hottest parts of the core. At such temperatures fission products are apt to diffuse rather easily through the fuel, particularly if the latter possesses a certain degree of porosity. In order to minimise the deposition of fission product activities in the primary circuit, the adoption of a method whereby a portion of the moderator forms a sheath for each fuel element has been considered. In so far as this may be porous, a reduced pressure has to be maintained inside the element so that some of the primary coolant flows inwards through the sheath, carrying the fission products back into the element. The inside of the latter is ducted to a fission-product trap to which the inflowing coolant carries the active atoms. The function of the trap is to hold up rare-gas activities for a period of several hours and to absorb, permanently, all other forms of activity.

There are several problems to be overcome in the successful application of the above principle, not least of which is that of back diffusion of the fission products through the pores of the moderator-cans. Ideally, the moderator should be produced in an impermeable form and either the sheaths should be sealed completely—in which case they would have to withstand the pressure built up by the released fission product gases—or alternatively, a small capillary should be left through the sheath to permit the passage of a flushing stream of coolant. It may be said at once, that ordinary pile-grade graphite, as used in present United Kingdom reactors, is much too porous for use in fuel element sheaths and it is necessary to develop graphites which are a factor of at least 10^5 better. (Impermeable graphite processes have been developed by the General Electric Company and by Hawker-Siddeley.)

PROPOSED 10 MW REACTOR

To investigate the problems of high-temperature gas-cooled reactors, it is desirable

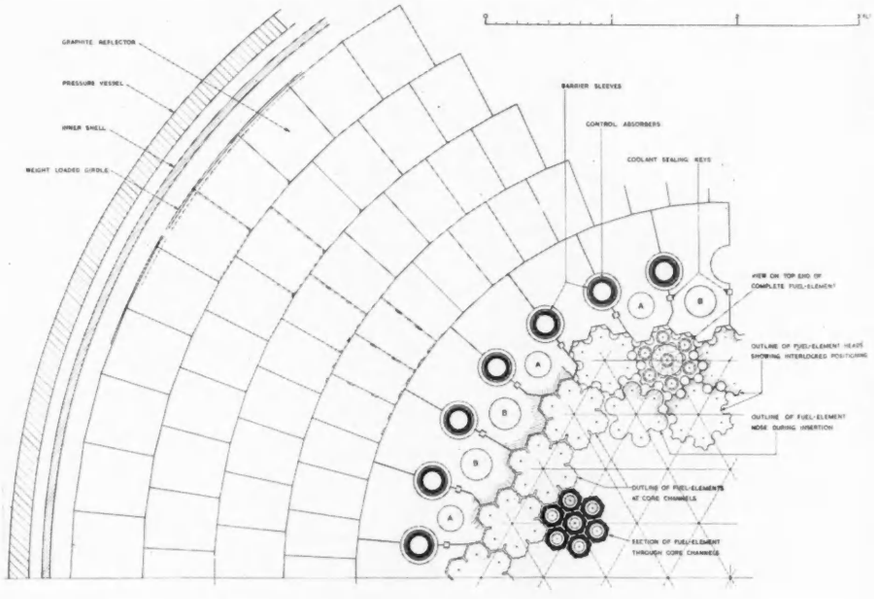

GRAPHITE REFLECTOR
PRESSURE VESSEL
INNER SHELL
WEIGHT LOADED GIRDLE
BARRIER SLEEVES
CONTROL ABSORBERS
COOLANT SEALING KEYS
VIEW ON TOP END OF COMPLETE FUEL-ELEMENT
OUTLINE OF FUEL-ELEMENT HEADS SHOWING INTERLOCKED POSITIONS
OUTLINE OF FUEL-ELEMENT NOSE DURING INSERTION
OUTLINE OF FUEL-ELEMENTS AT CORE CHANNELS
SECTION OF FUEL-ELEMENT THROUGH CORE CHANNELS

Fig. 5 (*below*) *Section of reactor core and reflector.*

to build and operate a reactor experiment which will incorporate most of the characteristics of a possible power unit. A preliminary design study of a 10 MW reactor experiment has been carried out at Harwell and further extensions to this work with the possibility of building such a system are under consideration. A general arrangement of the reactor, as envisaged during the preliminary design study, is shown in Figs. 2 and 3, and although further work on design detail will certainly involve many modifications, the drawing serves to illustrate the basic principles which would underly the final design.

The fuel elements in this system are constructed from graphite, uranium 235, and thorium. Each fuel element consists of seven closely packed rods, united to form a hexagonal array, as illustrated in Fig. 4. The construction of each fuel rod conforms to the principles outlined in the previous section, in having a sheath of graphite on the outside and a mixture of moderator, fissile and fertile materials inside the sheath. In the particular design illustrated in the drawing, the mixture forms an annular fuel insert around a central graphite spine, but, alternatively, it could be in the form of a solid rod within the sheath. Each fuel rod contains at its upper end an inlet vent containing a porous plug through which a bleed flow of coolant gas passes, while at the bottom, each of the seven rods is vented into a common duct in a locating block. The block holds them together and seats on to a hollow mounting spike through which fission products are extracted.

Each fuel element is 8 ft (approximately 2·4 metres) long and the individual rods, each a little over 6 ft long, are sealed to the bottom block and retained with metal bolts. At the upper end, the rods are joined to a spider-shaped block by metal cap-bolts and diaphragm washers to accommodate any unequal growth or expansion. An appreciable length change in an individual rod will not induce serious resisting forces since the diaphragm mounting washers will readily yield at the working temperature.

Sixty-one of the seven rod fuel elements make up the core of the reactor, the actual core geometry being roughly a cylinder of 4 ft length and diameter (Fig. 5). The closely packed rods have surfaces shaped to define a number of passages through which the coolant passes, the total voidage in the core due to these being approximately 13 per cent of the total core volume. The fuel elements make up not only the 4 ft length of core but also the end reflectors, roughly 2 ft thick at each end. Around the assembled fuel elements is a side reflector made up of graphite columns 8 ft in height with an overall diameter of 10½ ft. About 5 per cent coolant voidage is provided in this side graphite.

HELIUM AT TEN ATMOSPHERES

Both the reflector columns and core elements stand vertically and are pivotally mounted on steel structural members inside a steel pressure vessel, the reflector being arranged to close on to the core to provide an expandable restraint at the top of the fuel elements. For a 10 MW output the coolant is helium, at 10 atmospheres pressure, which enters and leaves by ducts near the top of the pressure vessel. The incoming coolant flows downward and maintains the inside of the pressure vessel and the bulk of the side reflector at a temperature not greatly different from the gas at 350° C. It subsequently flows upward through the core from which it emerges into a nimonic chamber at a mixed mean temperature of 750° C. The outflowing gas is transferred through a nimonic lined duct to the primary heat exchanger which is water cooled in the arrangement illustrated. It should be noted that the nimonic chambers and ducts are externally cooled by the incoming coolant and they have no structural function. No part of the primary circuit which has to withstand the full coolant working pressure is normally exposed to gas at more than 350° C.

Secondary cooling water emerges from the primary heat exchanger at a relatively low temperature, that is, about 75° C, so that no excessive pressurisation is required and a heat exchanger of small dimensions results from the large temperature difference between the hot gas and the cooling water. Other possible alternative arrangements using an intermediate heat transfer fluid to avoid any possibility of water leakage into the main circuit might be considered. No attempt to generate steam and power is contemplated in this study. A feature in the primary cooling circuit is the proposal to avoid shaft seals and to use instead completely enclosed motors and compressors with gas bearings. The inset view in Fig. 2 shows a single circuit with two circulators in series, an arrangement which avoids control valves. However, alternative systems using parallel circuits are worth further consideration.

CONTROL

Control of the reactor is exercised by means of a curtain of absorbing rods, 30 in number, moving in vertical channels near to the inside boundary of the reflector. These provide a small negative reactivity for shut-down and their removal compensates for temperature coefficient, poison and depletion, a total range of reactivity between 14 and 15 per cent being controlled. The possibility of using boron as a burnable poison in the fuel inserts as a means of reducing the depletion compensation required from the control rods is also considered. It is proposed that the control rods would be actuated by cable drives, as shown in Fig. 3, with the provision of magnetic clutches in the winding mechanisms to release the cables in the event of an emergency shut-down requirement. In order to protect the actuators from any primary circuit activity, zirconium sleeves are provided which isolate these control mechanisms from the circuit gas and thereby simplify maintenance.

In a reactor of this type it is important that it should be possible to load and unload fuel-elements without disturbing the helium coolant in the primary circuit. Accordingly, a charge-discharge machine capable of transferring elements through a gas lock is required, and the lower end of such a machine is shown in Fig. 2. The relative infrequency of fuel charging would enable the work to be carried out at a convenient shut-down period when gas temperatures are low and pressure correspondingly reduced.

The fission products pumped from the bottom of the fuel elements are passed through a fission product trapping system based on the use of active charcoal absorption beds. The emergent helium will still contain the longest period krypton and xenon activities since these are merely delayed. This gas will also go through a chemical purifier to remove O_2, CO_2, CO and N_2O before returning to the main cooling circuit. It is anticipated that the main problem which will be encountered in the reactor experiment will revolve around the effectiveness of the traps and chemical purifiers. If the oxidising impurities in the primary circuit could not be maintained in the region of a few parts per million, then the amount of mass transfer of carbon with unprotected fuel elements may cause embarrassment. Again, excessive radioactivity could set very stringent requirements on the leak tightness of the primary gas circuits, which might be extremely difficult to meet.

HTGC ZERO ENERGY FACILITY

In order to resolve a number of uncertainties in the physics of high-temperature systems and in the values of nuclear parameters used in the calculations, a zero energy reactor is being constructed at the atomic energy establishment, Winfrith. A special feature of this system is the fact that the critical assemblies will be contained in an atmosphere of circulating nitrogen which can be raised to very high temperatures by means of electrical heaters. It will be possible to raise the core temperatures to about 800 to 900° C, and the reflector temperatures to about 400° C. Thermal insulation between core and reflector will make it possible for their temperatures to be separately controlled. The High Temperature Zero Energy Reactor, to which reference was made in Atomic Review last week, is intended for general investigations of very hot systems. Its initial use will be to carry out tests on an assembly representing the proposed High Temperature Reactor Experiment.

NOTICES OF MEETINGS

British Institute of Management

LONDON
Elbourne Memorial Lecture on "The Great To-Morrow," by the Earl of Verulam. Royal Commonwealth Society, Northumberland Avenue, W.C.2. Fri., 3 Oct., 8 p.m.

Engineers' Guild

LONDON
Annual General Meeting. Discussion on "The Changing Pattern of Leadership," opened by Mr. A. R. Cooper. Metropolitan Branch. Caxton Hall, off Victoria Street, S.W.1. Tues., 23 Sept., 6 p.m.*

Institute of Petroleum

LONDON
"Harmful Effects of Electrostatic Charges on Machinery and Lubricating Oils," by Dr. T. Salomon. Wed., 17 Sept., 5.30 p.m.*

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
Presidential Address, by Professor J. Small. Tues., 7 Oct., 6.30 p.m.

Institution of Locomotive Engineers

LONDON
Presidential Address, by R. Arbuthnott. Institution of Mechanical Engineers, 1 Birdcage Walk, St. James's Park, S.W.1. Wed., 17 Sept., 5.30 p.m.*

Institution of Production Engineers

BIRMINGHAM
Various short technical films. Birmingham Section. College of Technology, Gosta Green, Birmingham. Wed., 17 Sept., 7.30 p.m.
SHREWSBURY
Film on "Copy Turning." Shrewsbury Section. Technical College, Shrewsbury. Wed., 24 Sept., 7.30 p.m.
WOLVERHAMPTON
"Engineering Metrology," by J. R. Adams. Wolverhampton Graduate Section. Wolverhampton and Staffordshire College of Technology, Wulfruna Street, Wolverhampton. Wed., 17 Sept., 7 p.m.

Liverpool Metallurgical Society

LIVERPOOL
Presidential Address on "Alternative Methods of Iron and Steel Production," by Dr. C. Bodsworth. Department of Metallurgy, University of Liverpool, 146 Brownlow Hill, Liverpool, 3. Thurs., 9 Oct., 7 p.m.

Society of Chemical Industry

NEWPORT
"Some Factors Affecting the Performance of Condenser and Heat Exchanger Tubes," by Dr. P. T. Gilbert. Corrosion Group. Joint meeting with the South Wales Section of the Society and the Cardiff Section of the Royal Institute of Chemistry. King's Head Hotel, Newport, Monmouth. Tues., 16 Sept., 7 p.m.

Society of Instrument Technology

LONDON
"Frequency Response Analysis Using Describing Function Method," by Professor C. J. West. Control Section. Manson House, Portland Place, W.1. Tues., 30 Sept., 6 p.m.*
CHESTER
Presidential Address. Chester Section. Grosvenor Museum, Grosvenor Street, Chester. Wed., 24 Sept., 7 p.m.
GLASGOW
"Circuitry of a Typical Digital Computer," by F. Bailie. Scottish Section. Scottish Building Centre, 425 Sauchiehall Street, Glasgow. Fri., 19 Sept., 7.15 p.m.
NOTTINGHAM
"Instrumentation in the Hosiery Industry," by D. L. Munden. East Midland Section. Nottingham and District Technical College, Shakespeare Street, Nottingham. Thurs., 18 Sept., 7 p.m.*

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than three weeks before the date of the meeting.

* An asterisk is placed where it is understood that refreshments are available prior to the time stated.

British Institute of Management, Management House, 80 Fetter Lane, London, E.C.4. (HOLborn 3456.)
Engineers' Guild, 78 Buckingham Gate, London, S.W.1. (ABBey 7315.)
Institute of Petroleum, 61 New Cavendish Street, London, W.1. (LANgham 3583.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2. (Central 5181.)
Institution of Locomotive Engineers, 28 Victoria Street, London, S.W.1. (ABBey 6672.)
Institution of Production Engineers, 10 Chesterfield Street London, W.1. (GROsvenor 5254.)
Liverpool Metallurgical Society, Greenhithe, Grosvenor Road, St. Helens, Lancs. (St. Helens 5879.)
Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. (BELgrave 3681.)
Society of Instrument Technology, 20 Queen Anne Street, London, W.1. (LANgham 4251.)

Special Article

MILITARY AIRCRAFT AT FARNBOROUGH

111 *Squadron—Hunters in formation aerobatics.*

FROM the spectacular viewpoint, the high spots of the Society of British Aircraft Constructors' flying display at Farnborough, which finished on Sunday last, were the aerobatics and flypasts by the Services—the Royal Navy's Sea Hawks, which performed a mass take off, and the Scimitars which are gradually replacing the Sea Hawks; the V-bombers, Jet Provost trainers and Hunter interceptors of the Royal Air Force. In particular, the 22 Hunters of 111 Squadron, in immaculate formation, gave a supreme display of aerobatics.

In the manufacturers' displays, the two larger V-bombers now in service, the Victor and the Vulcan Mark 1, demonstrated the manoeuvre developed for delivering a nuclear-bomb—a half loop and roll-off-the-top, very impressive when performed by such large aircraft. Both these aircraft are to carry the "stand-off" bomb.

VICTOR

The Victor, now in service with RAF Bomber Command, has flown at altitudes above 50,000 ft and has exceeded the speed of sound. The Mark 1 now in service is powered by four Armstrong Siddeley Sapphire turbojets; a later mark will be powered by Rolls-Royce Conways.

Some details of the construction of the Victor's wing—claimed to be "fail-safe," i.e., of slow crack-spreading character, have recently been released. As is well-known, Handley Page have done much work on electric-resistance spot welding, and the thick "sandwich"-type skins, which make up the top and bottom members of the wing multiple torsion box, have spanwise-corrugated cores spot-welded to the outer member. At the joints of inner and outer wing, and of wing to fuselage, cross-sectional forgings which run the full chord length of the primary wing box are butted together and joined by tension bolts, virtually buried in slots in the forgings. The latter are inserted in and bolted to the sandwich skin, the core being cut away and the core load being transferred through double plates.

VULCAN

A. V. Roe and Company Limited, Manchester, also displayed their air-to-ground missile (the "stand-off" bomb) mounted below the belly of a Vulcan bomber; and the Vulcan Mark 2, which is intended to carry the missile and which has only recently carried out its first flight, made its public debut. In comparison with the Vulcan, Mark 1, which has a wingspan of 99 ft, the Mark 2, spanning 111 ft, has an appreciable greater wing area, and towards the wing tip has a fairly pronounced droop on the leading edge. This modification has been made to enable the aircraft to operate at higher altitude and to take full advantage of the increased thrust available from the four Bristol Olympus 200 series, 16,000 lb-plus turbojets (the Mark 1, Vulcan has an earlier, less powerful version of the Olympus).

Of the "stand-off" bomb, few details have been released, except that it is powered (most likely by solid fuel rocket) and guided. Bearing in mind that the overall length of the Vulcan (both marks) is 97 ft 1 in, it would seem from the illustration that the stand-off bomb is about 37 ft long.

NA 39 NAVAL STRIKE AIRCRAFT

Of the military aircraft on view at Farnborough, greatest interest was centred on the NA 39 naval strike aircraft, by Blackburn and General Aircraft Limited, Brough, E. Yorkshire, seen in public for the first time. Very little official information has been released about this carrier-borne low-level attacker, but it is believed to be transonic rather than supersonic.

The aircraft is powered by two de Havilland Gyron Junior turbojets installed in nacelles on either side of the fuselage. The "bulges" apparent on the latter (but not very clearly revealed in the accompanying illustration), are explained by Blackburn's claim—surely controversial?—that the NA 39 is "the first aircraft in the world to embody full area rule design." It is also stated to incorporate boundary-layer control, probably in the form of blowing air over the flaps, and, possibly over the wing leading edge also. Air for this purpose is supplied from air bleed muffs surrounding the combustion system of each engine.

The high-slung tailplane has made it possible to use the entire tail-end of the fuselage as air-brakes, as illustrated.

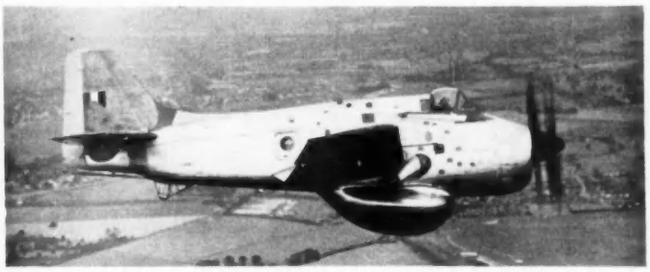
EARLY WARNING GANNET

The Fleet Air Arm's new early-warning-radar Gannet AEW 3 "flying control centre," for directing fighters and seeking out enemy vessels, built by the Fairey Aviation Company Limited, Hayes, Middlesex, has a massive under-fuselage radar scanner, and the two rear cockpits of earlier Gannet versions have been deleted. It is, like the other Gannet variations, powered by an Armstrong Siddeley Double Mamba turbo-prop.

De Havilland's Sea Vixen two-seat all-weather fighter, now in production for the Navy, will shortly replace the Sea Venom on carrier-borne service.

Equipped with comprehensive search and interception radar, the Sea Vixen carries four de Havilland Firestreak guided missiles, with 28 2-in air-to-air rockets as a secondary armament stowed in retractable Microcell racks in the underside of the fuselage. A further 96 2-in rockets in four external packs may be carried as an alternative weapon to the Firestreak. Other

Victor with air brakes in operation.



combinations of weapons include ground-attack rockets and bombs for the strike role, and long-range external fuel tanks may also be carried. The Sea Vixen it is claimed, is notable for its control stability at transonic and supersonic speeds combined with its excellent slow-flying characteristics—so essential for carrier operations. Its wide range of action and its operational flexibility make it suitable both for all-weather fighting and for the strike-reconnaissance role.

(Above left) On the NA39 the whole tail end of the fuselage is split and hinged to form air brakes.

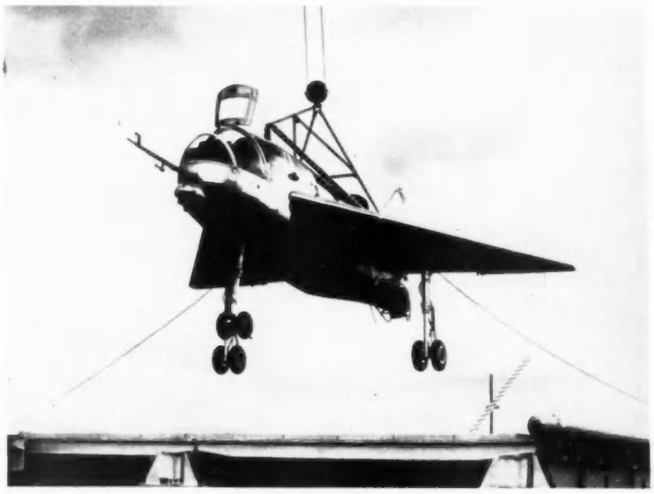
LIGHTNING INTERCEPTOR

Britain's fastest aircraft, the P1B single-seat all-weather interceptor now under development by the English Electric Company Limited, Warton, Lancashire, has now somewhat ineptly been named the Lightning. (A wartime American fighter of the same name was not particularly popular with British pilots !) It has now been officially confirmed that the Lightning has a Mach 2 plus performance—its makers quote a top speed (height unspecified) of 1,500 m.p.h.

Both single-seat operational and two-seat trainer versions of the Lightning have been ordered for the Royal Air Force. Equipped with Ferranti Airpass radar, de Havilland Firestreak guided missiles, 30 mm Aden cannon, and powered by two Rolls-Royce Avon turbojets with reheat, the Lightning is one of the most potent fighters in the world. It can be fitted with a rocket pack containing a Napier Double Scorpion rocket engine for sustained flying at extreme altitude.

The Lightning can be flown on one engine, making it easy for a pilot to return to base if one engine fails. Glide approaches by supersonic aircraft are extremely hazardous and an engine failure in a single-engined supersonic aircraft generally results in the pilot baling out and the aircraft being lost. With two engines, the Lightning can maintain supersonic speed without using reheat. The two engines also allow a complete and thorough duplication of all the essential services in the aircraft. If one engine fails, the aircraft does not develop asymmetric characteristics because both engines exhaust along the centre-line of the fuselage. By setting one engine in front of, and rather below the other, the aircraft has the thrust of two engines for the frontal area of appreciably less than two.

(Above right) The Gannet AEW3 "flying control centre", equipped with early-warning radar.



(Right) The SC1 vertical take-off research aircraft is now on its first untethered hovering trials.

An auto-pilot is fitted to the Lightning to make the task of flying the aircraft as simple as possible. This will give the pilot time to concentrate on the actual interception of the target while the aircraft "flies" itself. Thus no second crew member is needed. Autostabilisation is also fitted, but is not an essential safety device.

The cockpit of the aircraft is refrigerated and air below freezing point is pumped into it as well as to much of the equipment in the aircraft, in order to overcome the effects of kinetic heating (the so-called "thermal barrier") at high speeds.

The Canberra U Mark 10 push-button-controlled target aircraft.

The "stand-off" bomb, on a Mark 1 Vulcan.

VTOL RESEARCH

An aircraft which may determine the entire trend of design was on view in the static park—the SC1 "VTOL" research aircraft designed and built by Short Brothers and Harland Limited, Belfast, under contract to the Ministry of Supply. A stubby little machine, it has a delta-wing planform, with no tailplane. The wing span is 23 ft 6 in, and the aircraft is 24 ft 5 in long. Power is provided by five Rolls-Royce RB 108 jet engines, four of which are mounted vertically in a central engine bay to provide lift, while the fifth exhausts horizontally at the tail for forward flight. The four lifting engines are mounted in crosswise pairs, each pair swinging on an axis, so that the lifting thrust centre may be directed fore and aft on transition from vertical to forward flight and vice versa. After vertical take-off the engines are inclined backwards to give a forward thrust component, and before vertical landing they can be moved forward to give braking thrust.

All five engines have a compressor bleed supplying high-pressure air to a common duct which feeds air nozzles used for stability control in hovering flight. These control nozzles are positioned at the wing tips and nose and tail fuselage. Emission of air from the nozzle is controlled by the aircraft's electro-hydraulic auto-stabiliser. This auto-stabiliser system provides automatic stability during hovering and transition to and from forward flight; it comprises two groups of three separate, but identical, channels, each group being paralleled mechanically to a common output shaft. The groups control respectively the pitch and roll move-

Continuing At Farnborough

ments of the aircraft by means of variable air jets located at the wing tips and at the nose and tail. If any one channel should develop a fault, a warning light informs the pilot and he can switch it out; but even if the faulty elements are left in, the two sound channels override the output and the system continues to function.

The aircraft's maiden flight—for which it used normal forward take-off technique—was in April, 1957. It made its first vertical take-off, while tethered in a specially constructed test gantry, in May, 1958, and full-scale hovering trials in the gantry began two months later. The trials are to be followed by free vertical take-off and later by transition to forward flight.

New versions of long-established service aircraft included two Canberra variants—the T Mark 11, shown by the English Electric Company Limited, a four seat aircraft for training the pilots and navigators of all-weather fighters in the use of airborne interception radar, the latter being installed in the nose; and the Canberra U Mark 10 pilotless target aircraft, shown in the static park by its constructors, Short Brothers and Harland Limited. This aircraft embodies the Short self-contained automatic approach and landing system.

All ancillary equipment in the Canberra U Mark 10 is also automatic. This comprises flaps, fuel, drag parachute, air brake, wheel braking and undercarriage systems, as well as associated command radio and ancillary services such as telemetry, navigation, miss distance recording, command destruction and other specialist equipment. Particularly interesting is the fact that the aircraft can be " push-button " flown not only from the ground, but also from the pilot's seat in the aircraft.

PUSH-BUTTON CANBERRA

The Canberra U Mark 10 has already flown in excess of 50,000 ft while under automatic control. During the flight the aircraft was pilot-monitored, but the pilot did not touch the controls throughout. Flights at high altitude were part of the intensive development programme during which the aircraft has many times taken off, carried out a designated flight plan, and returned to make a perfect landing—all while under automatic control. It is claimed that the high altitude and speed range of the new Canberra place Britain ahead of the United States and other countries in this aspect of guided weapon testing. America has as yet no comparable " drone " or target aircraft.

The latest Hunter, shown by Hawker Aircraft Limited, Kingston-on-Thames, is the naval Hunter Mark 8—a two-seat version on order for the Fleet Air Arm, basically the same as the T Mark 7 but incorporating an arrester hook and some instrument changes to suit it for naval operation. Also making a first appearance was the Mark 8 Javelin all-weather fighter, by Gloster Aircraft Company Limited, Hucclecote, with a much enhanced performance resulting from its reheat Sapphire 200 series turbojets.

ENGINES AT FARNBOROUGH

In large aircraft there is a trend towards installing auxiliary power units as self-contained sources of compressed air for engine starting, air-conditioning systems, and so on; at the same time such units provide a source of constant-speed shaft power for driving alternators or hydraulic pumps. Accordingly, several engine manufacturers showed such units this year at Farnborough.

AIRBORNE POWER PACKS

Armstrong Siddeley Motors Limited, Coventry, have an agreement with the AiResearch Manufacturing Division of the Garrett Corporation, USA, to manufacture under licence auxiliary-power gas-turbines capable of supplying up to 210 lb per min of air at 75 lb per sq. in and 190° C; or shaft power up to 440 s.h.p.; or any combination of compressed air and shaft power. The unit can be installed either within the aircraft or fitted into a ground servicing trolley. Armstrong Siddeley are also to make AiResearch air-turbine starters under licence, capable of starting all types of turbine engine and operating on compressed air at 50 lb per sq. in. They can also be used in conjunction with cartridge-starting or fuel-combustion starting systems to starting. The turbine, operating at 46,000 r.p.m., drives the alternator through two-stage helical reduction gearing. Under sea-level standard atmosphere conditions, the unit gives an air bleed of 549 cu. ft per min at a pressure of 44 lb per sq. in abs. The electrical output is 32 kW at sea level, 15 kW at 30,000 ft.

The Artouste 510 airborne auxiliary power plant, made by Blackburn and General Aircraft Limited, Brough, East Yorkshire, is in production for the Royal Air Force and the Royal Canadian Air Force. It provides both shaft power and air bleed. Weighing 400 lb, and measuring 73½ in long by 24 in diameter, the Artouste has a sea-level rating of 16 kVA and 2·4 lb per sec of air, or 40 kVA and no air.

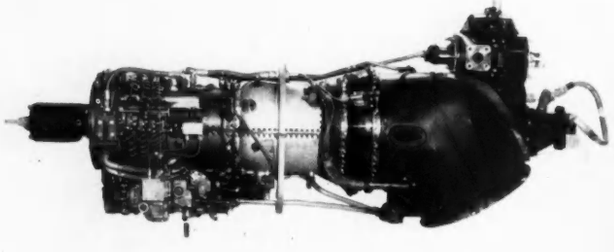
Also on view the high-pressure Palouste air-bleed unit, developed to meet the latest air-turbine starting requirements. It delivers 2 lb per sec of air at 85 lb per sq. in abs., and weighs 250 lb. The overall length is 45½ in and the height 27½ in. (An article on the Blackburn-Turbomeca series of small gas-turbines was published in ENGINEERING on p. 667, 23 May '58). Blackburn also showed their new A.129 free turbine, rated initially at 840 s.h.p. They expect to develop it to 950 s.h.p. This engine will be available in various forms—turbojet, air-bleed, fixed-shaft and free turbine units.

GNOME

The de Havilland Engine Company Limited are now building under licence for the General Electric Company of America, the GE T58 1,000 h.p. shaft turbine, the English version of which will be known as the Gnome. The T58, a compact lightweight flexible engine of the free-turbine type, is being developed in America for the United States Navy. From the production viewpoint it is attractive, embodying an unusual amount of fabricated sheet metal and the minimum of costly forgings; it is designed for good maintenance accessibility. At its present 1,000 h.p. rating, it fills a gap in the available horse-power spectrum in this country. There is also plenty of " stretch " in it—de Havilland expect developed versions to produce up to 1,500 h.p.

In the first place, de Havilland see the Gnome as a helicopter shaft-drive power plant, for which the free-turbine layout is eminently suitable; but it has many other potential uses, such as an auxiliary power unit, or as a power plant for STOL aircraft where one or more engines may be geared to a shaft driving two or more propellers. De Havilland's latest proposal is for an orthodox propeller-turbine version. Such an engine would be particularly valuable for aircraft of the " DC3 replacement class "—say, four-turboprop versions of the Fokker Friendship or Handley Page Herald.

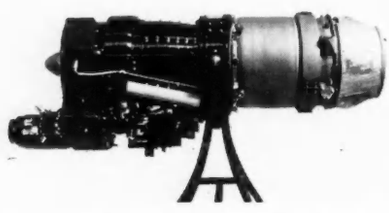
The basic Gnome engine, as shown at Farnborough and in the accompanying illustration, comprises a ten-stage axial compressor, a fully annular combustion system, a two-stage turbine driving the compressor, followed by a mechanically-free power turbine. The inlet guide vanes and first three rows of stator blades have controllable variable incidence. The power drive may be direct from the rear of the engine or through reduction gearing mounted above the exhaust duct. Without reduction gearing, the Gnome develops 1,000 s.h.p. and has a specific fuel consumption of 0·65 lb per s.h.p. per hour, it



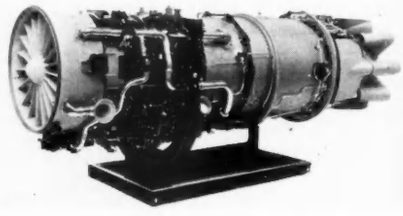
The de Havilland Gnome shaft turbine helicopter version.

increase the energy level. The 40 h.p. ATS 25 series starter weighs 12 lb, and the 90 h.p. ATS 100 series weighs 20 lb.

The auxiliary power unit shown by Rover Gas Turbines Limited, Solihull, comprises a Rover 1 S/60 gas-turbine coupled to a Rotax 208V three-phase 400 c/s alternator, all housed within a stainless steel casing, and cooled by a mechanically-driven fan drawing air through an inlet—which also serves the engine intake—in the bottom of the housing. The power pack's main purposes are to provide emergency electrical power for essential flight services, and to provide an independent compressed-air supply for engine



Rolls-Royce 2,750 lb thrust RB 145 turbojet with jet-lift applications.



Conway turbojet with noise suppressor (right)—as installed in Boeing 707.

is 54·8 in long, 19·6 in high, and 18·2 in wide, and weighs 275 lb—giving a high power/weight ratio of 3·64 : 1. With reduction gearing, output is slightly reduced—975 s.h.p., and specific fuel consumption rises to 0·667 lb per s.h.p. per hour; weight increases to 350 lb, and the power/weight ratio is 2·79 : 1. The unit is about 6 in longer, 8 in higher, and slightly narrower.

P 181 AND 182

The P 181 and P 182 gas-turbines announced last year by Armstrong Siddeley Motors, and aimed to fill the same power gap as the Gnome, are being developed simultaneously—the P 181 for rotary wing aircraft and the P182 as a turbo-prop for fixed wing aircraft. They have been designed as robust, simple and compact engines capable of operating under adverse conditions with the minimum amount of servicing. They use the same compressor, combustion chamber and turbine assemblies. The principle differences are in the reduction gearing and final drives. Both engines incorporate a three-stage compressor comprising two axial stages and one centrifugal stage. The compressor is driven by a two-stage turbine with a free power turbine driving the output shaft through reduction gearing. In the case of the P181 a power take-off can be provided either from the front or the rear of the engine.

The principal particulars of the two engines are as follows.

—	P 181	P 182
Shaft horse-power ..	1,020	1,100
Plus thrust, lb	200	200
Compressor r.p.m. ..	20,000	20,000
Power turbine	14,600	20,000
Propeller r.p.m., max. ..	—	1,448
Specific fuel consumption	0·71 lb per s.h.p. per hr	0·65 lb per e.h.p. per hr
Weight, lb	550	600
Diameter, in	27·4	27·4
Length, in	60	60

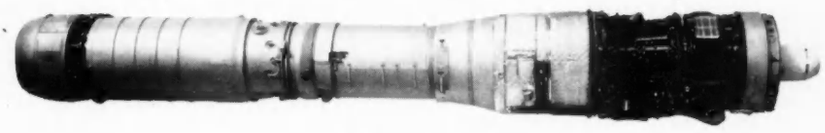
TYNE, PROTEUS AND ELAND

Among the larger turbo-props, the Rolls-Royce Tyne, which is to power the Vickers Vanguard airliner, was demonstrated on its flying testbed, the Tyne Ambassador. A second Ambassador is being converted to Tynes for use by BEA crews to build up flight experience. The Tyne, rated at 5,525 e.h.p., is a compact twin-spool axial-compressor engine with a high compression ratio, giving the very low specific fuel consumption of 0·388 lb per e.h.p. per hour.

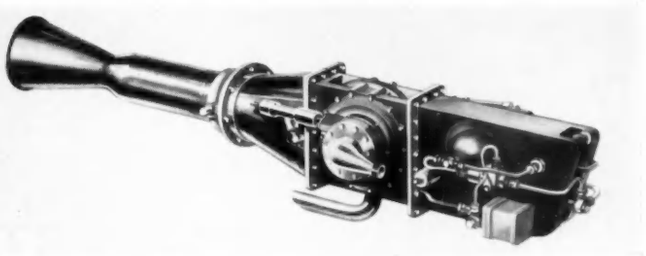
One of the recently-announced 760 series of Proteus propeller turbines, made by Bristol Aero-Engines Limited, was shown in sectioned form—the 4,445 h.p. Proteus 765 which is to power the Britannia 320 series of long-range airliners. (The Proteus 755 in the Britannia 300 and 301's currently in service develops 4,160 h.p.) Three new Proteus variants were announced at Farnborough; the 761 incorporates modifications to the compressor which give an improvement in specific fuel consumption of nearly 3 per cent under cruising conditions. It develops maximum power at considerably lower compressor r.p.m. and this is expected to have a beneficial effect on the already high overhaul life. The Proteus 762, almost identical to the 761, for a different type of fuel injector and a recalibrated control unit, gives 5 per cent more power for take-off with the same cruise rating and fuel consumption. By means of a simple adjustment of the governor setting, the cruise power of both the Proteus 761 and 762 can be increased, and the engine will then become the third variant of the series—the Proteus 765, which still retains the reduced specific fuel consumption of the 761.

TURBOJETS

Of the Rolls-Royce turbo-jet exhibits, one is a newcomer—the 2,750 lb-thrust RB 145, developed from the 2,010 lb-thrust RB 108 light-weight engine of which five are installed in the Short VTOL research aircraft. The RB 145, it is stated, is suited to a wide range of aircraft applications, of which no doubt vertical lift is one, since the power-to-weight ratio is claimed to be unusually high.



The fully-variable afterburning jet pipe of the Avon RA 24 R, for the super Lightning all-weather fighter.



Armstrong Siddeley 500 lb-thrust rocket engine.

The Conway by-pass turbo-jet, which is in production in its 17,250 lb-thrust military version for the Victor Mark 2 bomber, is scheduled for the DC8 airliners going to Trans-Canadian Air Lines and Alitalia, the Boeing 707-420 airliner on order for BOAC, Air India International, Lufthansa and Varig, and later for BOAC's Vickers VC10 fleet. It was the Boeing 707's Conway RCo10, developing 16,500 lb-thrust and fitted with thrust reverser, and convoluted, slotted noise suppressor, that was on view in the static display. Eventually the civil Conways will be developed up to 18,500 lb-thrust. Weight and consumption figures have not yet been quoted for the Conway series; they are expected to be appreciably lower than on a conventional turbo-jet.

The latest of the military Avons, the RA24, which develops 11,250 lb-thrust without afterburning, was shown fitted with the afterburning jet pipe, with petrol-type fully-variable nozzle, that has been developed specifically for the Lighting supersonic interceptor.

Canada's powerful supersonic turbojet, the 20,000 lb-thrust Iroquois designed and built by Orenda Engines Limited, Melton, Ontario, has now completed 6,000 hours of test running both in flight and on the test bed—including sustained runs in a simulated-flight high-altitude cell at a Mach number of 2 at altitudes between 60,000 and 70,000 ft. Also in the test cell have been carried out some 100 relights at over 60,000 ft—with no failure. One of the secrets of the Iroquois, success in relighting at high altitude is the use of oxygen-injection. Very soon the Iroquois will replace the Pratt & Whitney J.75 turbo-jet on the supersonic Arrow all-weather fighter production line at Avro Canada's works.

Bristol's most successful turbo-jet, the Orpheus Mark 803, developing 4,850 lb thrust at a weight of only 825 lb, is on order for some 16 aircraft. It has already flown in the Folland Gnat, the Italian Fiat G.91, the French Dassault Etendend, the French Breguet Taon aircraft which recently broke the world's 1,000 kilometre closed-circuit speed record at an average speed of 668 m.p.h., the American prototype Lockheed Jet Star utility transport aircraft, and the Japanese Fuiji TIF-2.

This year the de Havilland Engine Company Limited, Leavesden, showed the Gyron D.Gy 2, with a design thrust rating of 20,000 lb; with afterburning, this engine has been running at a thrust greater than 29,000 lb, which de Havilland believe to be the highest thrust yet achieved by a turbo-jet engine. The Gyron D. Gy 2 is specified for the Hawker P. 1121 supersonic fighter aircraft which is going forward as a private venture; flight development of the engine is being carried out at Hatfield in the Gyron Sperrin test bed. The Gyron D. Gy 2 has a diameter of 49·9 in, an overall length of 155·5 in, and weighs 4,200 lb.

The D.G. J10 version of the Gyron Junior is on view at Farnborough for the first time; this engine incorporates various modifications which give it a much greater thrust than the 7,000 lb of the earlier D.G. J1 engine, also on view. The D.G. J10 Gyron Junior is under development with afterburning for supersonic applications, and de Havilland are showing an afterburning system giving a 40 per cent increase in static thrust at an operating temperature of 2,000° K. Gyron Junior engines are, of course, fitted in the new Blackburn NA 39 naval strike aircraft which is flying in the display.

ROCKETS

Several rocket engine developments have been announced, and some were on view at Farnborough, but technical data are severely restricted. The PR. 23 liquid-propellent rocket shown by Armstrong Siddeley Motors is a small engine intended for such duties as trimming the attitude and velocity of long-range ballistic missiles, and for assisting the control of aircraft at very high altitudes where the normal control surfaces would not be sufficiently effective. It could also be used for trimming heavily-loaded aircraft nose-up or nose-down at take-off, or for providing additional thrust in emergencies. The PR. 23 develops a sea-level thrust of 500 lb ad weighs 30 to 32 lb. The type of propellents used in the PR. 23 have not been disclosed; Armstrong Siddeley's earlier and larger rocket engines, the Snarler and the Screamer, operated on kerosine and liquid oxygen.

The Triple Scorpion shown by D. Napier and Son Limited, Luton, consists of a Double Scorpion with a third barrel added, giving corresponding 50 per cent power increase. The Double Scorpion, it may be recalled, is installed in the Scorpion-Canberra flying testbed which for a brief period last year captured the aeroplane world altitude record. The Scorpion family operate on hydrogen peroxide and liquid kerosine, which are fed separately to the combustion chambers by a single turbo-pump.

The new Double Spectre rocket engine announced recently by the de Havilland Engine Company was not on view at Farnborough, but its component engines, the fixed-thrust Spectre 4 and fully-variable-thrust Spectre 5, were. All the Spectre engines operate on hydrogen peroxide and kerosine. The Spectre 4, in production as an assisted take-off unit for the V bombers, is essentially similar to the controllable-thrust Spectre, which was fitted in the Saunders Roe SR 53 mixed power interceptor, but without the thrust-control mechanism and with a smaller sump. It has a diameter of 21·4 in and an overall length of 59·2 in; corresponding figures for the Spectre 5 are 27 in and 56·4 in. The new Double Spectre is a high-thrust unit suitable for interceptor and missile applications, and consists of a Spectre 4 mounted above a Spectre 5.

The Human Element

Membership of Millions

When the Trades Union Congress last met at Bournemouth (as it has been doing this year) it was the year of the General Strike, a year of unhappy memories for organised labour. The membership then was half what it is now and the trade union movement was neither as powerful nor as respected as it is to-day.

The annual report of the TUC hints that it would like to reach the 10 million mark for its centenary year in 1968. Even this comparatively ambitious figure assumes that over half the working population will remain outside the trade union movement. There are three main reasons why this should be so. First of all, it has been found exceedingly difficult to bring women into the unions. Secondly, there is a great deal of indifference among workers who allow their membership to lapse too readily and who rally round for a card only when there is a major union crisis. Finally, there are fairly wide fluctuations, especially in the membership of the big general unions to which has to be added the fall in membership in unions in contracting industries among which the railways are at present outstanding. Big efforts are made from time to time to organise shop workers and clerks but success seems to be limited and localised. Organised labour is powerful but it is not as fashionable among workers as it often appears.

The Age of Discretion

The Trades Union Congress is over for another year. It has closed with a chorus of criticism from outsiders about the dullness and orderliness of its proceedings run by elderly trade union statesmen who have lost their youthful fire and enthusiasm. There is doubtless truth in this view but not the whole of the truth.

Publicity organs of all kinds are apt to be critical today if they are not presented with a vivid story for their customers. The crowd wants to see a spectacle. News is only worth printing if it can go into the headlines as noisy and discordant. This is a comment on the public as much as on the TUC.

One argument for a certain amount of staidness is the need for the trade union movement to learn as soon as it can that its own future is at stake if it tries to set itself up as an independent estate in the realm which can make and unmake governments, co-operate with one kind of government but not with another or pursue political theories to the ultimate conclusion with little regard for the electorate. Some of the hotheads would push it that way. They have had some indication this year so far that the public will not stand for it. The older men know this. They " got tough " in the days when their movement was fighting for recognition and power. Now it has both. Learning to use it is very dull. There is something in the idea, though not everything, of the TUC being a horse in a cartoon rather than a bull in a china shop.

Burden on the Bulge

An anonymous article in the July issue of *Occupational Psychology*, " Young People at Work: Some Statistics," discusses the employment and training problems of the population " bulge " in the early 1960's. It argues that the problem for these age groups born towards the end of or just after the last war will be one of training rather than of unemployment.

Technical progress should be sufficient to absorb young persons, if they can become qualified; and indeed it will be the young workers who will be expected to produce the hoped-for growing rate of productivity. The article goes on to say that if there is any question of unemployment it will be the older workers, the part-time workers and the married women who experience it.

This rising productivity and growing proportion of older people are two sides of the same penny. If the older age groups are to be maintained in pensions in increasing numbers, the means can be found of doing so only by putting the burden on the younger age groups. If these in turn are to raise their own standard of living there must be a significant rise in the level of productivity in industry. This means more workers in servicing and planning activities which means more training. As the article says, it is here that there is danger of the chain breaking down.

Engineering Workers Hover

The magic of 3 per cent has not dazzled the engineering unions. They have not been impressed with the fact that some other large unions have settled for this size of increase in 1958. They think that the employers can afford to pay more. A conference of union representatives from the Confederation of Shipbuilding and Engineering Unions is to meet at York after this issue goes to press to consider the next step. By then they will have the reply from the shipbuilding employers about another and parallel wage demand.

Sir Kenneth Hague, the president of the employers' federation, has left the door wide open when he said that there should be further negotiation to avoid industrial friction which means that the last word has not come from the employers if the unions show an accommodating attitude. The fact is that everyone wishes wages in the engineering industry as a whole to be high enough to attract labour from other industries, especially from distribution, but everybody knows that the unfederated employers in particular are paying higher than the nationally agreed levels already. In the engineering industry more than any other, negotiated wage rates are only nominal and therefore the arguments of both sides have an air of unreality.

At the moment tempers are cool and attitudes reasonable. The meeting at York will be the next opportunity for showing whether they are going to remain so.

Resisting Contraction

Large industries contract only reluctantly. It would be surprising if it were not so. To-day, however, there are powerful interests organised to slow the process down whenever possible. The latest examples are the railways and the London bus services.

Last week the Manchester district council of the National Union of Railwaymen, which is noted for its militancy on most union issues, expressed its grave concern at the cuts in passenger services which form part of the economies which have been speeded up to pay for the last pay increase. In like manner the London bus workers representatives have had much to say about the cut in schedules. In both cases the imputation has been that controllable forces have not been curbed, in the one case by further nationalisation, in the other by better management.

It would be surprising if organised labour did not show some fight in the face of industrial contraction. No union thrives on a contracting membership whatever be its cause. The public interest is not, however, served where a union can ally itself with top management and delay contraction by helping to distort the industrial pattern by successfully demanding subsidies or unduly high prices in the absence of competition.

Examples are not lacking of industries, including their trade union representatives, which have tried to take this way out without success. Perhaps the outstanding example is cotton textiles where in many cases indifferent management and organised labour have fought together without impressive results to delay the industry's contraction. The very least that can be expected of labour when contraction sets in is that it should allow a delay in recruitment to give natural wastage a chance to let the labour force fit declining output. The coal miners can see the point. It seems to be more difficult to drive home in the transport industries.

Forecasting Apprentice Failures

A paper read before the British Association by two members of the Applied Psychology Unit of Edinburgh University this year dealt with " The Selection of Shipbuilding and Marine Engineering Apprentices." In 1956 a Glasgow shipbuilding concern approached the unit to see if it could help to reduce the heavy losses due to failure of apprentices in courses held by the company. The idea was to establish if possible a forecast by written test and interview before the courses began.

On the shipbuilding side the losses would have been reduced from 42 to 31 per cent if the unit's tests had been used. On the marine side they would have come down from 55 to 39 per cent. The company were also interested in having a forecast on the bright boys and results on this were encouraging. It has also been possible to predict with some accuracy the order of merit of boys on the courses.

The selection procedure so far has not been able to control the very wide variations in percentages of successes from one course to another. The techniques employed, however, have been comparatively inexpensive in time and materials and the results have been on the whole encouraging. The whole subject needs a great deal more attention than it gets at present. If the present checks alone are used to keep wastage down in technical education (in its widest sense) over the next generations, the results may be appalling. The need of the moment is for a rapid expansion in youthful manpower for training, a larger training organisation and more teachers. Progress is being made. The circumstances are, however, ideal for getting square pegs with round holes and some shapes which will fit neither. Good and widely used techniques for forecasting the misuse of training facilities are vitally important.

Inspecting the Inspector

Friction is common in factories between the production and the inspection departments. An interesting paper on the subject was read this year to the British Association (Psychology Section) by Mr. R. M. McKenzie of Edinburgh University. Starting with the known tension which exists between the two departments he went on to show the degree of fallibility possible by certain experiments.

These included experiments on a noise-testing inspection, a surface-finishing inspection, examining sub-assemblies, " go—not go " gauging, human inspection against a micrometer on parts, and the marking of examination papers. Variations in all cases were important. The last example is specially interesting since lecturers marking papers bring a high degree of intelligence to the task and therefore it might be presumed a high degree of consistency. Yet variations of some size were noted, not only as between marks given by different markers on the same questions, but between marks awarded by the same marker on the same questions on different occasions.

The lesson of this seems to be not only that inspectors must move with tact and humility on the job but that it would be no bad thing to establish exact criteria of inspection and to inspect the inspectors from time to time.

Metals and Materials

HARVESTING A THREE YEAR NUCLEAR CROP

Atomic Energy Exhibits at Geneva

Concluded from page 326, September 5

THE last of the three year nuclear harvest is almost gathered in. To-day is the final day of the Second International Conference on the Peaceful Uses of Atomic Energy and to-morrow the Atoms for Peace Exhibition, also taking place in Geneva, comes to an end. On 22 August in an introductory article, we suggested how a number of advances in nuclear thinking might be reflected in the industrial exhibition. The article continued with descriptions of exhibits shown by companies and consortia prepared to undertake complete power reactor projects. A second article was devoted to reactor plant and instrumentation, and a third to experimental equipment. The series, prepared in advance of the meeting, concludes with notes on the materials of nuclear energy, their fabrication and the problems of handling them.

Materials and Fabrication

The advance of atomic energy depends on the availability of materials that can withstand the rigorous conditions of atmosphere, pressure, temperature and radiation met in nuclear reactors, and yet can be formed and machined at reasonable cost. The exhibits of several companies demonstrate their part in providing such materials, either in extracting them from ores or adapting them to the circumstances in which they will be used.

Basic Materials

The *Rio Tinto Group* central exhibit is a specimen of uranium concentrate containing over 80 per cent uranium oxide (U_3O_8) in the form of sodium uranate. This basic material for atomic energy—the so-called "yellow cake"—is produced from the eight mines of the group in Canada and Australia. The mines represent a combined annual production equivalent to more than 5,500 tons of uranium metal and the company claim to be the biggest producer of raw materials for atomic energy in the free world. The Rio Tinto group's production centres at Mary Kathleen in Australia and in Canada's Blind River uranium field are ready to supply uranium for peaceful uses. *Humphrey's and Glasgow's* Canadian subsidiary is building the country's first thorium recovery plant for Rio Tinto-Dow Limited at Blind River.

Fig. 23 Wrought and finished products, including fuel-element support brackets, in ICI zirconium and zirconium alloys.

Nuclear materials of many kinds are produced by the *Union Carbide Corporation*, who will be exhibiting in the American section. Uranium concentrates, a uniform material containing a minimum of 75 per cent of uranium oxide (U_3O_8), are produced in large commercial tonnages in western United States. After further processing these concentrates may become high-fired uranium dioxide, a high-purity sintered product, which can be made readily available containing various enrichments of uranium 235; or uranyl sulphate, another fuel material. Other products of Union Carbide include nuclear graphite, used as moderator or with boron for shielding purposes; columbium, a low thermal-neutron absorption material employed in the manufacture of high-temperature alloys and for fuel element cladding; vanadium, which may be similarly used and in addition is resistant to molten-sodium attack and is compatible with uranium; rare gases for blanketing, cooling and bubble chambers; tantalum, which is resistant to liquid metal coolants and is recommended as a container for molten plutonium-iron eutectic; and various solvent extractants for uranium ores.

The long experience of *ICI Metals Division* in the processing of nuclear materials, including the production of porous membranes for uranium diffusion plants, the rolling and extruding of uranium, and the production of heavy water, will be represented on the ICI stand, together with recent work. On a section of the stand entitled "new metals" will be shown such metals as beryllium, vanadium and niobium, which are the subject of advanced research and development because of their likely use as materials for sheathing nuclear fuel. Beryllium is of outstanding interest for use in advanced high-temperature gas-cooled reactors; vanadium and niobium, which are being used in the experimental liquid-metal cooled fast reactor at Dounreay, might also be required for sodium-cooled graphite-moderated thermal reactors. Simple products made in these unusual metals of the future will be on display.

ICI pioneered the manufacture of titanium and titanium alloys in Great Britain and operate the largest melting and fabrication plant in Europe, making sheet, strip, rod, tube, wire and plate. Similar products can be made in zirconium and also fuel cans and fuel-element support brackets as will be used at Berkeley. The high strength-to-weight ratio of titanium, its good corrosion resistance and the fact that, after irradiation in a nuclear reactor, it remains radioactive for only a short time, make it suitable for components in control rods and fuel charge-discharge machines. An ingot of titanium weighing nearly 2 tons will be on display. Zirconium is a nuclear engineering metal with very useful properties, having high mechanical strength at moderately elevated temperatures, low neutron absorption and good compatibility with water. For fuel sheathing and structural components in boiling and pressurised-water reactors, alloyed zirconium is probably the best material. Examples of wrought and finished products, including fuel element support brackets in ICI zirconium and zirconium alloys are shown in Fig. 23.

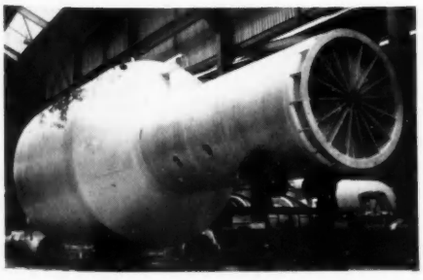


Fig. 24 Core tank fabricated in 99·5 per cent purity aluminium by the APV Company Limited for a MERLIN *type reactor.*

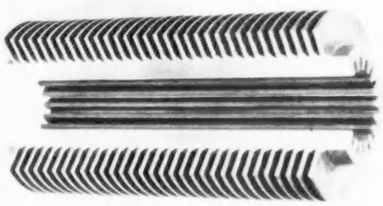


Fig. 25 Sectioned view of tube having both interior and exterior extended surface, made by Tubes Limited to give good heat transfer.

The *Mond Nickel Company Limited* and its associate *Henry Wiggin and Company Limited*, are exhibiting at the exhibition, and their stand will feature the world-wide service of technical information about nickel containing materials and the role of nickel in the field of nuclear engineering. Some 60 different technical publications—many of them in French, German or Italian—will support information panels dealing with the subjects of corrosion-resistance, strength at high temperatures, welding, controlled thermal expansion, and the cobalt-free characteristics of Mond nickel pellets.

A new method of producing heavy water has been developed by the British company of *Constructors John Brown Limited*. The process, details of which have been revealed at the Second International Exhibition of the Peaceful Uses of Atomic Energy, is for the extraction of heavy hydrogen from ammonia synthesis gas by ammonia exchange. The company states that although this method has been known in broad principle for some time, its research department has now developed a new route which enables costs to be reduced considerably, to below the price at present asked by the United States Atomic Energy Commission. Until now, as a result of large-scale production, the USAEC has been able to sell heavy water at 28 dol per lb—a price which made it uneconomical for most countries to produce their own. The new British technique, in addition to providing the first serious competition for the American process, is expected to have considerable attraction for smaller countries with atomic energy programmes. Even at unfavourable sites the cost of production by this method is appreciably below the USAEC price. Constructors John Brown Limited is a wholly owned subsidiary of John Brown and Company Limited, and is thus linked with the Hawker Siddeley—John Brown Nuclear Power Company, on whose stand at the exhibition it will be showing an animated flow sheet of the new process.

A section of the AEI—John Thomson Nuclear Energy Company stand will be devoted to a display by *Nuclear Graphite Limited*. The display illustrates the part they play in the consortium. Nuclear Graphite is specialising in machining graphite components for nuclear reactors. Specially designed plant has been installed enabling them to machine large tonnages of very pure graphite to extremely fine tolerances. The display will show graphite bricks and tiles similar to those to be used in the Berkeley reactors. Also on show will be a wide variety of graphite engineering components, indicating the skill and versatility of the various machining processes.

A graphite which is completely impermeable to gases and highly resistant to gaseous corrosion has been developed for nuclear applications by the *General Electric Company's* research laboratories. Such a graphite offers potentialities as a fuel-canning

Continuing Metals and Materials

material and as a moderator for use with liquid-metal coolants. The impermeability of this material is demonstrated by a display of a graphite tube, the inside of which is charged, at a temperature well above 500° C, with carbon dioxide at a pressure of 10 atmospheres while a vacuum is maintained at the outer surface.

A number of examples will also be shown of the applications of GEC heavy alloy as a shielding material for the absorption of gamma radiation This sintered tungsten-based alloy is used throughout the world by universities, hospitals, industry, and atomic-energy authorities in the manufacture of products such as spheres for remote-handling equipment, isotope transport containers, shielding blocks for nuclear propulsion units and therapeutic apparatus.

Fabricating Materials

Special problems arise in the fabrication of nuclear materials and a number of companies will be showing examples of manufactured products. The nuclear engineering components being exhibited by Tube Investments on the stand of *TI Nuclear Engineering Limited* include longitudinal and spirally finned fuel-element cans for gas and water-cooled reactors; various designs of heat-exchanger tubes in mild steel, chromium molybdenum alloy steel, stainless steel, aluminium and copper; charge standpipe assemblies; fuel element supports and chutes; charge tubes and plugs; control rods and tubes; restraint tie bars; pressure vessels; and high-pressure cylinders for nitrogen, oxygen, carbon dioxide and air. Many of these items will be shown by the *Talbot Stead Tube Company*. In addition, there will be a range of tubes in zirconium and its alloys, beryllium, niobium, vanadium, tantalum, and titanium. Other exhibits include bellows pumps, pressure control instruments and various components in polytetrafluorethylene; mechanical seals for circulation fans, gas compressors, and rotary pump and mixing vessel applications, and packings.

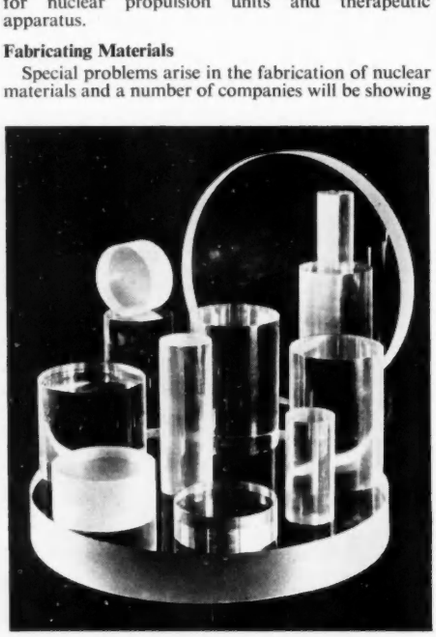


Fig. 26 Organic scintillators made by Nash and Thompson Limited.

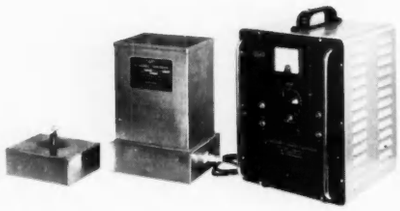


Fig. 27 Ultrasonic cleaning apparatus made by Dawe Instruments Limited.

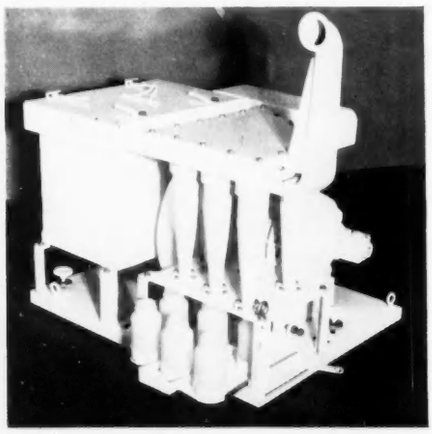


Fig. 28 Vokes mobile swarf collector for use where radioactive metals are machined.

ICI Metals Division now makes many specialised products for nuclear reactors. Aluminium finned tubes have been supplied for canning at many of the experimental reactors at Harwell and elsewhere, for instance in the plutonium-producing piles at Windscale. *Marston Excelsior Limited* have been responsible for the assembly of enriched fuel elements for the water-cooled research reactors DIDO, LIDO, DIMPLE and MERLIN. For the world's first commercial power station at Calder Hall, England, ICI Metals Division supplied ancillary coolers and brazed assemblies for the burst slug monitoring system, and nearly 400 miles of ICI heat-exchanger tubing is being made for the nuclear power stations at Berkeley and Bradwell. In addition, ICI produces extended-surface fuel cans with longitudinal or helical fins made by extrusion or roll forming in both aluminium and magnesium alloy (Magnox), suitable for gas-cooled reactors. A display of a number of these fuel cans, showing the intricate shapes now produced, will also include a 12 ft sample length of zirconium fuel can made by ICI for AB Atomenergi in connection with the Swedish atomic development programme. ICI also manufactures Integron finned tubing for heat exchangers.

Marston Excelsior Limited will show light-alloy pipework, heat exchangers and condensers, gas coolers and compressor units. A tube bundle used for connecting burst-slug detection gear to the interior of a reactor has 12 stainless-steel tubes brazed into a plate 14½ in diameter and 21 ft long. A plate-type fuel element made for British research reactors will be featured in the exhibit, and also bursting discs, for safeguarding systems against excessive pressure.

The *Fairey Aviation Company Limited* will be showing, on the stand of Atomic Power Constructions Limited, aluminium fabrications for atomic energy plant, fuel containers for the Calder Hall and Windscale power stations, and examples of the Fairey investment moulding process. It should be pointed out that the model nuclear power station referred to in our account of the Atomic Power Constructions exhibit (22 August, page 233) represents a 500 MW station and not, as we stated, one of 150 MW.

Ultrasonic techniques are now firmly established for cutting holes and patterns of any shape, with speed and accuracy, in hard and brittle materials. The low-power ultrasonic drill manufactured by *Mullard Equipment Limited* has special applications chiefly in the laboratory, in the machining of reactor fuel elements.

A combined stand will show the work of the *APV Company Limited*, who will exhibit products of their fabrication division in aluminium and stainless steel, and of their foundry's associated company, *APV-Paramount Limited*, who will display castings in stainless and special alloy steels. The APV Company have fabricated the aluminium core tanks for most of the British research reactors and some for overseas, and examples of tanks which they have made for DIDO, MERLIN (Fig. 24) and NEPTUNE type reactors are illustrated together with a display of weld samples and techniques. APV-Paramount Limited show one of the reactor guide pan steel castings supplied to the General Electric Company Limited and Simon-Carves Limited for the Hunterston nuclear power station and also lantern and plug castings in stainless steel for the Bradwell nuclear power station. In addition castings are shown in a series of corrosion and heat resisting materials.

The exhibits being shown by *Tubes Limited* on the stand of TI Nuclear Engineering are two examples of heat-exchanger tubes in which increased heat transfer properties are obtained by increasing both the internal and the external surface area, as may be seen in Fig. 25. This increase is obtained, in the bore, by the production of tubes with integral longitudinal internal fins or flutes, and on the outside diameter, by a process of welding on a helical strip fin, the pitch and dimensions of which can be varied. The company are also showing a thermal sleeve for use in a nuclear heat-exchanger, which is manufactured by a tubular forging process.

The *Chesterfield Tube Company Limited* will be showing on the same stand: hot-finished seamless square headers, cold-drawn seamless steel tubes, a seamless steel air receiver, a 2,000 cu. ft seamless steel nitrogen cylinder, extruded boron tubes as used in reactor control mechanisms, and various other tubular items.

Miscellaneous Materials

One section of the *Shell Petroleum Company* exhibit is devoted to research into radiation-resistant lubricants. Another part, which includes a model of the Bradwell station, will indicate the application of atomic-power lubricants and high-grade conventional lubricants in nuclear power stations.

The use of polytetrafluorethylene (PTFE) in atomic energy work is represented by *Crane Packing Limited* on the stand of TI Nuclear Engineering. Gland packings, mechanical shaft seals and similar items will be on display.

Nash and Thompson Limited are exhibiting their range of organic scintillators, a selection of which are illustrated in Fig. 26. On the *Chance-Pilkington* stand are examples of radiation-shielding glasses. Stabilised glasses have their compositions amended in order to reduce the tendency to discoloration upon receipt of high dosages of short wavelength radiation.

Handling Radioactive Materials

The handling of radioactive materials in the laboratory involves special precautions, and in addition to the manipulators and glove boxes built for this purpose, a number of ancillary items have

Fig. 29 Hobson—AERE honeycomb isotope unit for handling samples inserted in nuclear reactors for irradiation.

Fig. 30 EMI hand and clothing monitor.

been developed, such as filters and ultrasonic cleaning apparatus. *Dawe Instruments*, for example, are showing equipment of this kind, as illustrated in Fig. 27, based on their type 1150 500 W Soniclean generator. The *Vokes Group* are exhibiting glove-box filters and their fume removal unit, together with a mobile swarf collector (Fig. 28) operated by remote control for use in laboratories where radioactive swarf is collected during machining operations. The *Fairey* exhibit will include a filter developed for use in hydraulic pressure lines up to 4,000 lb per sq. in, filtering particles of 4 microns and larger.

A glove cabinet to UKAEA requirements, together with a flexible glove cabinet for less dangerous work and handling tongs, is being exhibited by *Townson and Mercer Limited*, while *GEC* will be demonstrating their heavy-duty power-operated manipulator. Two companies showing devices for handling radioactive isotopes are *General Radiological Limited*, who will display tools for this purpose, and *H. M. Hobson Limited*, whose honeycomb unit shown in Fig. 29 is designed for insertion and withdrawal of irradiated samples from a nuclear reactor. Final protection for those engaged in handling radioactive materials is provided by an efficient personnel monitoring system. The EMI hand and clothing monitor is shown in Fig. 30.

Using Radioisotopes

Applications of radioactive isotopes include gauges and monitoring devices.

Ekco nucleonic gauges are a means of measuring an ever-increasing variety of materials produced by continuous-flow processes, and the latest developments in nucleonic gauging techniques are being displayed with emphasis on automatic control of production processes. A type N582 nucleonic gauge will be demonstrated in a specially constructed display unit to illustrate individual control of screw-down at each side of a calender or rolling mill, utilising automatic programmed scanning of the material being produced. A nucleonic gauge is being shown with a measuring head using the *Bremsstrahlung* radiation from a strontium 90 source to extend the measurement range to cover brass, steel, copper and other materials up to 0·4 in (10 mm) thick. Employing transistors and printed-circuit technique, the type N563 gamma backscatter gauge is a self-contained portable unit for measuring the thickness of pipe walls or sheet materials to which access is possible on one side only. The measuring head is contained in a convenient pistol-grip unit and provides two ranges of measurement, 0 to 0·25 in (0 to 6 mm) and 0·2 to 0·75 in (5 mm to 19 mm). The Ekco type N611 fluid density gauge is finding rapidly expanding application in industries where the product is at some stage in the form of a fluid or slurry. It will be demonstrated in a specially built display unit illustrating its ability to differentiate between liquids of different specific gravity.

The package monitor type 210 made by *Isotope Developments Limited* is used for checking the contents of cans, tubes, cartons of tablets and similar items on high speed packaging lines. Incorrectly filled containers are automatically rejected. The measuring head incorporates a Geiger-Muller tube and a small beta source.

Research and Development

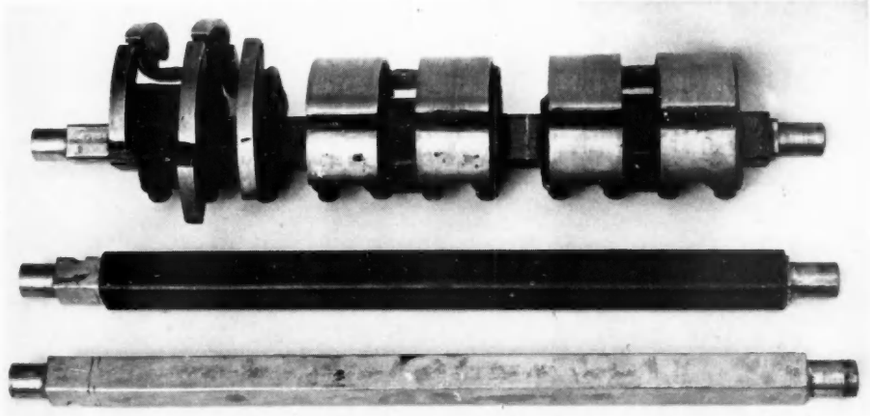
INSULATING SHAFTS

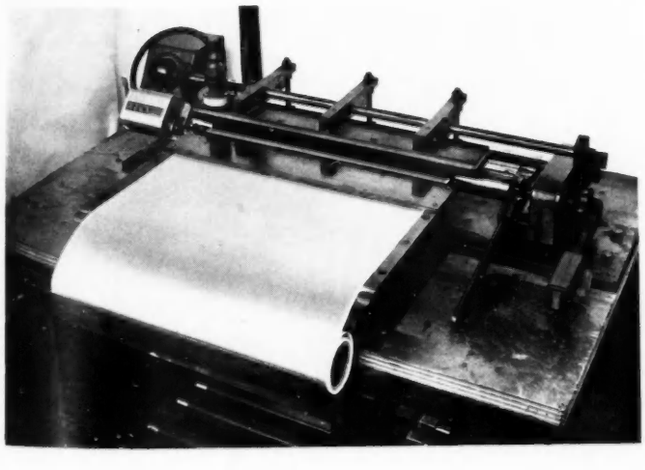
An improved method of insulating the shaft on a traction motor reverser switch has been developed by London Transport's mechanical engineering department, Acton Works. The switch arm is of the rotating drum type, with contacts clamped to a square central shaft insulated for 600 V. Failure from loose clamping as a result of shrinkage of the micafolium and shellac insulation around the shaft promoted the investigation into other methods of insulation. Now glass cloth impregnated with epoxy resin is used, and has proved successful under severe service conditions; many hundreds of switches are being modified.

Initial experiments in applying the micafolium to the shaft in the normal way with a hot iron but using a bakelised cement instead of shellac for the final application, proved unsuccessful: shrinkage still occurred. Therefore, micafolium was discarded as the main insulating medium, and a composition of synthetic resin and mica dust was developed for application to the shaft in a specially prepared mould. The trial shafts were given a final coating of anti-tracking paint, and the contacts clamped directly on to the moulded insulation.

This form of insulation proved satisfactory both in mechanical strength and insulating properties. But difficulties in handling the compound retarded the production rate. It has also been shown from experience that the compound is too hard to ensure the contact clamps gripping and remaining tight. Further experiments were therefore made using insulation in the form of a glass cloth wrapper impregnated with an epoxy resin which acts as an adhesive under heat and pressure. The glass cloth was obtained in roll form to suit the full width of the shaft, and the 13 turns required to give the desired insulation thickness were wrapped by hand on the trial shafts. The tests were successful.

It then became necessary to evolve a method of speeding up the process, and a special fixture was manufactured as shown in the illustration. The glass cloth is fed under tension on to the shaft, which is rotated by a hand-operated ratchet device. As the shaft rotates the heat and pressure required to activate the adhesive are applied by a hand-operated electrically-heated press head. When the desired number of turns is indicated on the counter attachment the glass cloth is cut and sealed. The insulated shaft is then pressed between angle formers to ensure accurate dimensions, and placed in an oven to cure the epoxy resin. Finally a coating of anti-tracking paint is applied.





(Above) The switch is of the rotating-drum type with contacts clamped to a square central shaft. Previously, shaft insulation shrinkage led to failure of the clamping.

(Left) The fixture now used to apply glass cloth insulation to the bar. The heater is shown lowered and in use.

NON-LINEAR FREE VIBRATIONS

In a paper " Free Vibration of Systems of One Degree of Freedom with Non-Linear Elastic Characteristic and Non-Linear Viscous-Type Damping," by S. Ziemba, a further development of cases dealt with previously is considered and a certain generalisation made of the problem of non-linear free vibrations of systems of one degree of freedom. The paper is published in *Archiwum Mechaniki Stosowanej* (vol. 10, No. 2, 1958).

The author concludes that four principal types of motion are obtainable. The first occurs if the system passes through the position of equilibrium no more than once. In this case, by choosing suitable initial conditions a system can be obtained which does not pass through the position of equilibrium at all. Second, the system may pass through the position of equilibrium a finite number of times. In this case the number of alternations can be modified by choosing the two characteristics in a suitable way. Third, the system may perform an infinite number of oscillations, the motion being alternating from the beginning. Fourth, the system performs in an acceptably long time a non-alternating motion and then an alternating motion, with the number of alternating oscillations increasing indefinitely as a function of time. This is important for, among other things, the design of elastic shock absorbers with viscous damping for single impulses.

Continuing **Research and Development**

HIGH VOLTAGES FOR CABLE RESEARCH

Voltages for the transmission of electrical power have risen steadily and are continuing to rise. At the recent International Conference on High Tension Networks (CIGRE) meeting, for example, mention was made of a test line in the United States operating at 750 kV. To meet the changing needs of electricity transmission systems, Enfield Cables Limited have constructed a new high-voltage laboratory at Brimsdown, Middlesex. The principal items of equipment are an impulse generator with an output voltage of 2·4 MV and an alternating-current test plant capable of providing 2·4 MVA at 600 kV to a test sample for 30 minutes.

The main equipment is housed in a laboratory with a floor area of 9,600 sq. ft and a clear height of 45 ft. The spaciousness provided by this arrangement is well shown in Fig. 1, attached. A reinforced-concrete frame is employed in the main structure, with the laboratory supported on 18 in square columns at 15 ft spacing. Prestressed concrete beams 3 ft 6 in deep, spaced at 7 ft 6 in, span the 80 ft roof. Natural lighting is provided by a continuously glazed clerestorey infilling on the north side, supplemented by east and west windows. The latter have vertical louvres of prestressed concrete to exclude direct sunlight. Provision of an adequate lighting factor at floor level presented a problem, but a solution was found by installing, at roof height, twelve 1 kW mercury-tungsten lamps and reflectors. Acoustic materials in the roof, using spattered vermiculite on metal lathing suspended below the beams, together with insulation boarding and acoustic tiling on the walls, have reduced the period of vibration of the hall to 1·9 seconds. On the front of the building is a four-floor office block.

A 12-stage, 2-column impulse generator, with an output voltage of 2·4 MV and a stored energy of 120 kW-sec, stands in the south-east corner of the laboratory and is shown in Fig. 2. The front and tail resistors are adjusted to produce a 1/50 microsecond wave shape on the test specimen. Shedded porcelains have been used for housing the stage capacitors and for the spacers; each stage capacitor being of 0·5 microfarad and charged from equipment incorporating metal rectifiers, which permit direct voltages from 0 to 200 kV to be obtained on each stage. Facilities for automatic polarity change-over have been incorporated.

For voltage measurement, a capacitance divider of 270 picofarads, constructed in three sections, is used. It is terminated by a low-voltage capacitance of variable steps. A low-capacitance lead is taken from the divider to a cathode-ray oscillascope, of the sealed-off type, with tubes operating at approximately 15 kV. Two tubes are provided, each fitted with a camera. These are shown in Fig. 3, with the impulse generator control desk on the left.

A series resonant circuit is employed in the high-voltage alternating-current testing plant. The power supply is taken from the 11 kV system to a feed transformer of 400 kVA, 30 minutes rating. The secondary of the feed transformer is connected in series with the test sample and the two transformer/reactor units. Each unit is designed to operate at 300 kV on the secondary winding; with both in series, 600 kV is obtained on the test sample at a continuous rating of 1·0 MVA. These units, and the feed transformer, are shown in Fig. 4. The reactance of each unit can be varied by about 40 : 1. The addition of a third transformer/reactor unit is permitted by the rating of the feed transformer, so that, at a later date,

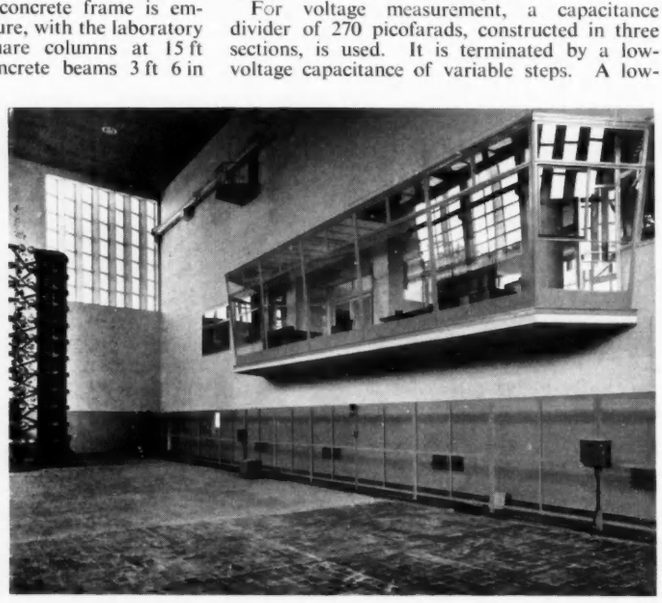


Fig. 1 (above) The 45 ft high interior of the electrical laboratory, showing the control room on the right.

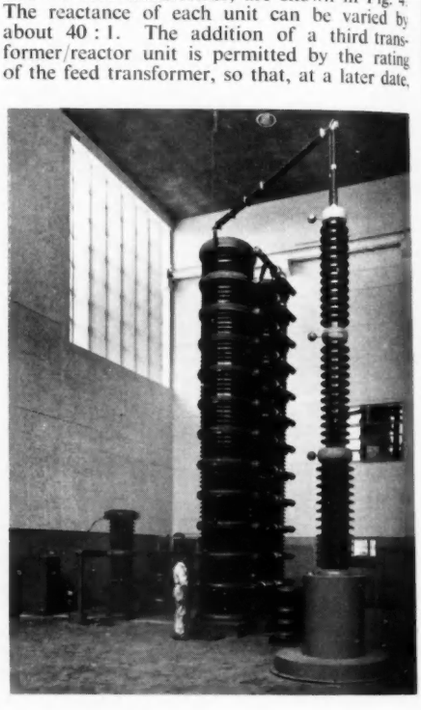


Fig. 2 (right) The 12-stage 2-column impulse generator has an output voltage of 2·4 MV and a stored energy of 120 kW-sec. On the right is a 270 picofarad capacity divider.

Fig. 3 Two cathode-ray tubes fitted with cameras are housed in the control room. The impulse generator control desk is on the left.

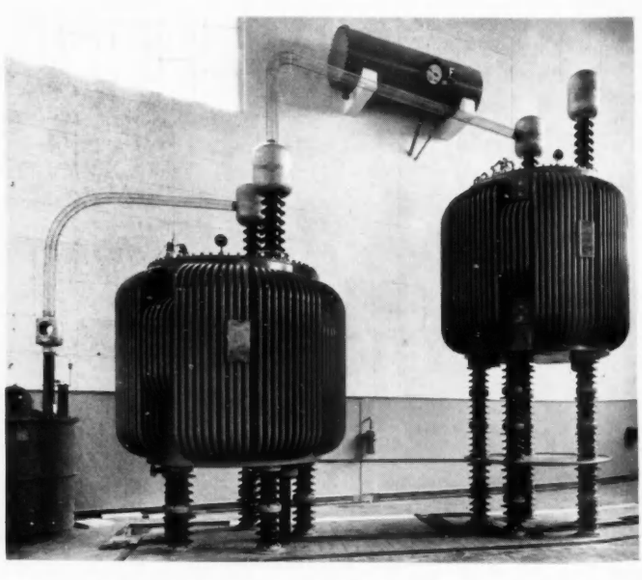


Fig. 4 The feed transformer, seen on the extreme left, operates in conjunction with two resonant transformer/reactor units to produce 600 kV at 2·4 MVA.

the capacity of the plant can be raised to 900 kV at 3·6 MVA, 30 minutes rating. Both the impulse generator and the a.c. test plant were supplied by Ferranti Limited, Hollinwood, Lancashire.

Among the reasons put forward by Enfield Cables for selecting a series-resonant circuit were that an improvement was obtained in the voltage waveform and that, should a test sample break down, it would detune the circuit and reduce the fault current to a fraction of its normal value, so that the sample did not suffer further damage (as it would with a parallel-resonant circuit). Furthermore, the series circuit is suitable for either series or parallel connection of the reactor/transformer units and the power for the test equipment is supplied at unity power factor.

For voltage measurement, a pair of 1·5 m diameter spheres, motorised for remote control from the control room, has been installed. Earth plates have been provided for both the a.c. and the impulse testing plant. On the latter, all earth connections are taken back to one common point. After discussion with many authorities, the company decided not to screen the building.

CHEMICAL MAGNETISATION

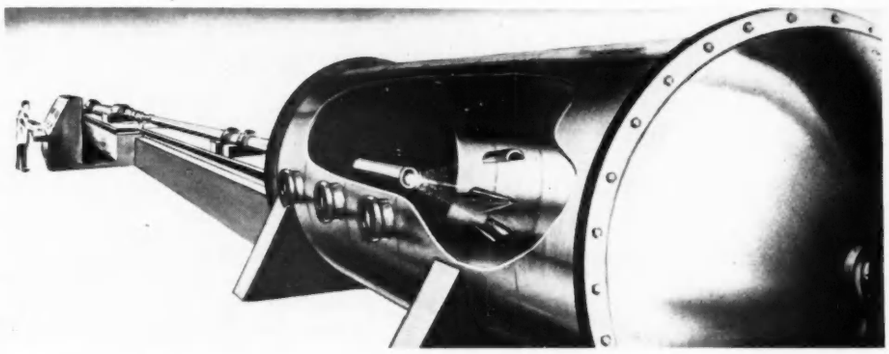
Permanent magnetism can be produced in several ways. One process under investigation at Tokyo University is described in a paper, "Experimental Studies of the Generation of Remanent Magnetisation of Ferromagnetic Minerals by Chemical Reactions," by T. Nagata and K. Kobayashi. The authors found that stable remanent magnetism could be produced during the reduction process from $\alpha\ Fe_2O_3$ to Fe_3O_4 under the influence of a magnetic field. Powder with a mean diameter of one micron was used, it being packed in a porcelain boat and reduced at 340° C for 20 hours in an atmosphere of hydrogen. To see how the reduction process proceeded, X-ray analyses were performed before and after the chemical reaction.

The remanent magnetism generated in the specimen after the suppression of the magnetic field, and the cooling in field free space was measured by an astatic magnetometer at room temperature. It was found that the intensity of "chemical remanent magnetism" varies linearly with the applied field and is intermediate between isothermal remanent magnetism and thermo-remanent magnetism. The magnetic and thermal stability of the chemical remanent magnetism resembled that of thermo-remanent magnetism and suggests that the physical mechanisms basic to the two processes are similar. Further experiments are being undertaken. The paper is published in the *Proceedings* of the Japan Academy (vol. 34, May, 1958).

SUBJECTING COMPONENTS TO NOISE

An experimental facility to assist in the design of components subject to the intense sound fields near rocket or jet motors has been constructed in the test laboratory of Sandia Corporation, Albuquerque, New Mexico, USA Components are mounted in pipes down which 500 watts of audio energy in the range 300 to 7,500 c/s can be fed. The plane waves travelling down the tube subject the component to the same variations in air pressure as would be experienced near a missile motor. The waves are absorbed at the far end of the pipe by lambs-wool cones.

Noise intensity in the pipes is varied by the use of different diameter pipes. In the present facility, pipes of 2¾, 3½, 4½ and 5½ in diameter are employed; but a larger facility is planned, which will use a tube of about 6 ft diameter.



One way of using the proposed hypersonic gun is to drive projectiles through the 3 in diameter barrel into a test chamber. While in the gun barrel, the model would be surrounded by a sabot, which separates upon reaching the chamber.

HYPERSONIC GUN

A gas-driven hypersonic gun is to be built by Convair Division of General Dynamics Corporation, San Diego, California, USA. It will produce speeds of up to 13,500 m.p.h. and will be used for advanced research on missiles and problems associated with the re-entry of space vehicles into the earth's atmosphere. The installation is expected to cost 500,000 dol.

Two methods of using the device are envisaged. In one, projectiles will be driven through a 100 ft long, 3 in gun barrel into test chambers at velocities of up to 20,000 ft per sec. In the second method, high-pressure high-velocity gas will pass over a stationary model suspended in a vast chamber. The first method is shown diagrammatically in the illustration.

The hypersonic facility will have a two-stage firing chamber using helium as the driving gas. Hydrogen and oxygen will be introduced into the helium, and the mixture will be ignited by an electric spark. The gun barrel will terminate in two interlinked chambers: the first will be a 50 ft blast tank, partly evacuated; the second will be a 500 ft tank at a lower pressure than the first. Operation of the test range will be possible with pressures between 10^{-3} and 2 atm.

Projectiles and stationary models will be shattered against the chamber walls by the short duration hypersonic "blow-down" blast from the gun muzzle. Observation of the tests will be accomplished by optical and electronic measuring techniques, which will include a schlieren system and equipment for sensing heat transfer and dynamic pressures. Instrumentation and test personnel will be housed in a protected enclosure. When a stationary model is being tested, the barrel of the gun will be loaded with high-pressure air. This air will be further compressed and accelerated by the explosive helium-hydrogen-oxygen mixture and ejected at high speed from the gun muzzle, past the model suspended from the roof of the chamber.

Dr. Zaka I. Slawsky, chief of the hyperballistics division, Naval Ordnance Laboratory, Silver Springs, Md., is a consultant to Convair on the proposed facility. Construction will be started in October and the gun will be ready for use by 1960.

LABORATORY DIFFUSION PUMP

The type 033A high-speed Metrovac diffusion pump has been developed by Metropolitan-Vickers Electrical Company Limited, Trafford Park, Manchester 17, for use in laboratory and small industrial vacuum applications, such as electron microscopy and mass spectrometry. It is a 3 in pump and is suitable where pressures in the range 10^{-3} to 10^{-6} mm of mercury are required.

The pump body is a water-jacketed cylinder of non-corrodible copper alloy enclosing an aluminium three-stage jet system. A detachable heating unit using a metal-sheathed radiant element, lagged in a polished aluminium cover, is fitted to the base of the pump. The unbaffled pumping speed for air at pressures below 10^{-3} mm mercury is 130 litres per second; with a standard baffle valve, the speed is 80 litres per second.

A detachable heating unit using a metal-sheathed radiant element is fitted to the base of the pump.

Design

RAIL BUSES ENTER SERVICE

British Railways have on order 22 lightweight diesel-powered railbuses for use on lines where the traffic potential is too small for the economical operation of bogie stock. Deliveries are now proceeding rapidly: the latest addition being three for the Midland Region, built by Park Royal Vehicles Limited; and two for the Western Region, built jointly by two road undertakings in the ownership of the British Transport Commission—Bristol Commercial Vehicles Limited, and Eastern Coach Works Limited, Lowestoft—both of which were acquired with the Tilling Group. The vehicles built for the Western Region incorporate some interesting design features. An exterior view of one of these rail buses is shown in the illustration at the top of this page, and a view of the control panel of one of the driving compartments in the illustration on the right.

Each Bristol/Eastern Coach Works rail bus, which is mounted on four wheels, can seat 56 passengers and has been arranged with a central entrance forming two saloons and luggage space. Their design and construction is based on principles used in the manufacture of the Bristol/Eastern Coach Works passenger-carrying road vehicles, and both the upholstery and decoration of the saloon conform generally to the Eastern Coach Works standard bus practice. The unladen weight is about 13½ tons, and the overall length is 42 ft 7 in. The power unit is a single underfloor 112 b.h.p. bus-type Gardner diesel engine, providing a maximum speed of 50 to 55 m.p.h. To ensure a clean air supply to the engine the air intake is taken from the roof by ducting.

The floor is lower than usual, being only about 7 in above the platform when the vehicle is laden, thus dispensing with a step and making it easier for boarding and alighting. The driving controls at each end of the rail bus are particularly simple in action, and the entire driving technique can be mastered within about 10 minutes.

The wheels are unique in this country, in that they are a resilient type made by the Svenska Aktibolaget Bromsregulator, Sweden. The rims are flexibly mounted, relative to the wheel centres, by a system of rubber "bobbins," thereby reducing wheel shock and noise, when traversing rail joints and similar unevennesses.

The braking system also is the first of its type in use in the United Kingdom and successfully eliminates wheel locking under wet or dry line conditions while maintaining optimum braking. It has been developed by the Dunlop Company Limited, and is known as the Dunlop Monitor Brake System. The braking effort is achieved by a monitor brake shoe which initiates and controls the main braking effort through disc-type brakes. The bus-type mechanical hand-brake operates on all four wheels and is sufficiently powerful, being assisted by the automatic servo action of the Monitor brake system, to allow the vehicle to continue to operate in the event of an air-brake failure.

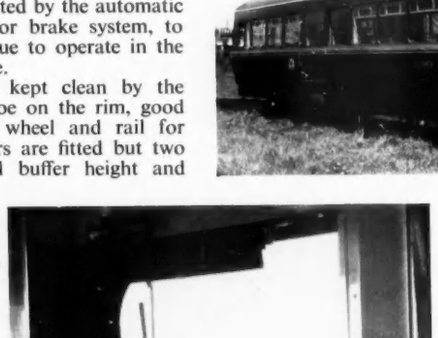
As the wheel rims are kept clean by the rubbing of the monitor shoe on the rim, good contact is made between wheel and rail for track-circuiting. No buffers are fitted but two tubular units, at standard buffer height and width, directly connected with diagonal struts to the main longitudinal frame members, support a bumper bar.

The general construction is based on an integral design having an all-steel underframing, while the body is constructed entirely of aluminium alloy extrusions and panelling, and is completely integrated with the underframe, thus providing maximum stiffness. Sound and thermal insulation is provided by filling the space between the interior and exterior panels throughout with a lightweight plastics insulating material. Acoustic panels, 2 in thick, are fitted below the floor.

The first three of five diesel-powered rail buses built for British Railways by Park Royal Vehicles Limited, Abbey Road, London, N.W.10, went into service on the Midland Region, British Railways, on 11 August. The vehicles, one of which is shown in the illustration on the right, will operate between Bedford and Northampton, and Bedford and Hitchin. Two similar rail buses are destined for the Scottish Region.

To ensure passenger comfort, a patented suspension is featured, the body being double-sprung from the axles by leaf and coil-spring systems. The 43 ft 4 in long body is designed to carry 50 seated and up to 50 standing, and also incorporates a large luggage compartment.

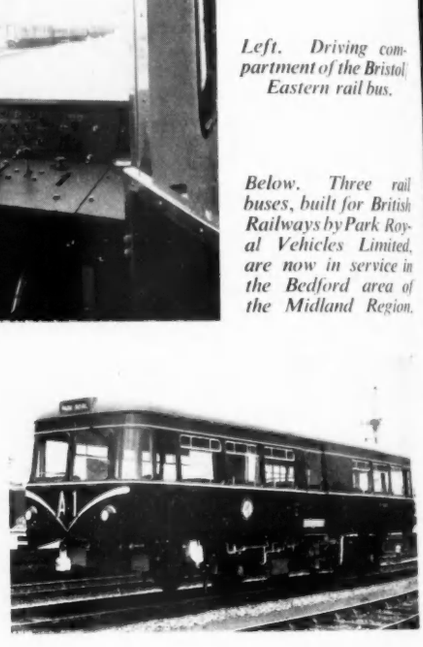
The rail buses incorporate a B.U.T. 150 b.h.p. six-cylinder underfloor-mounted horizontal oil engine. The transmission is similar to that in the multiple-unit stock and comprises a 20 in fluid coupling, freewheel unit, four-speed direct air-operated epicyclic gearbox and an axle-mounted reversing final drive geared for a maximum speed of 60 m.p.h. Driver's controls are provided at each end of the car, and are of the electro-pneumatic type. The fuel capacity allows a range of approximately 450 miles. Air-operated brakes of Clayton Dewandre supply are fitted. The buses have control and transmission equipment by British United Traction Limited which is similar to that used in approximately 1,000 of the 1,050 multiple unit diesel power cars in service with British Railways. The special railbus suspension is also built under a BUT licence.

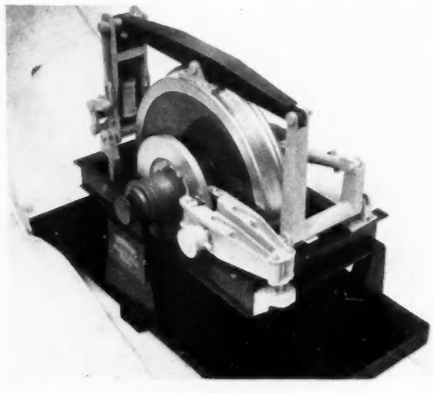


Above. The two rail buses built by Bristol/Eastern Coach Works have unusual wheels of Swedish design and Dunlop disc brakes.

Left. Driving compartment of the Bristol/Eastern rail bus.

Below. Three rail buses, built for British Railways by Park Royal Vehicles Limited, are now in service in the Bedford area of the Midland Region.





The layout of the Dunlop monitor brake system is shown in this model.

MONITOR BRAKE SYSTEM FOR RAIL BUS

The Dunlop monitor braking system and disc brakes fitted to rail buses belonging to the Bristol/Eastern Coachworks operate in the following manner. A beam carrying a monitor shoe is pivoted on two vertical links which, in turn, pivot about their mounting brackets. An air-operating cylinder is positioned in one vertical link, thereby bringing the monitor shoe into contact with the wheel rim, and causing the vertical links and beam to swing in the direction of wheel rotation. An extension arm from the second vertical link energises a hydraulic double-acting master cylinder, supplying fluid under pressure to the caliper-operating cylinder and forcing the friction pads into contact with the disc.

The air supply to the brake-operating cylinder is controlled manually by a lever on the driver's desk. Each brake is independent, although all brakes are applied together. Hydraulic fluid is supplied from two tanks, each tank having separate compartments for each brake. The oil level in each tank is shown by a sight tube. Vents for both the air and caliper cylinders are piped through transparent plastics hoses to points above possible flood water level. The vent-pipe extremities are fitted with filters.

A model of the layout of the Dunlop braking system is shown in the illustration, left, on this page. Brakes can be mechanically operated by means of a handbrake lever in each driver's cab. Pad clearances with brakes off are automatically maintained at a constant amount, as no adjustment is necessary. The pads are changed, when fully worn, by the removal of a split-pin and nut, thereby allowing the carrier plate to be withdrawn. Caliper arms are then opened by the tool provided and the new pads secured in position.

PROGRESS IN NAVAL ARCHITECTURE

*A Review of the Principles of Ship Resistance, Strength, Performance and Vibration**

By J. F. C. Conn, D.SC., M.I.N.A.

Professor of Naval Architecture
University of Glasgow

SHIP building is an ancient industry, and the study of naval architecture dates from very early times. Shipbuilders have not always relied on the preparation of precise designs, based on the results of calculations, before beginning construction. Despite such an absence of method the accumulated experience and the skill of the craftsmen combined to produce ships of high quality. The full rigged sailing ship represented perhaps the final triumph of empiricism, where the hull design and the structure of the rigging were the fruits of a long period of evolution. With the change from wood to steel and from sail to steam came also the scientific approach.

At the present time most of those countries which have large shipbuilding industries possess organisations for research in shipbuilding. There is, therefore, a large annual output of papers giving the results of orginal work in many branches of naval architecture, but chiefly in resistance, propulsion, performance, structural strength and ship vibration.

The aim of this paper is to review our knowledge in certain branches of naval architecture and to comment briefly on the recent advances.

RESISTANCE

Many early workers investigated the resistance of ships, but to little effect. In 1867 William Froude began towing ship models on the River Dart. His remarkable abilities in both theory and experiment enabled striking progress to be made. With the support of the British Admiralty, Froude designed and built the first ship testing tank at Chelston Cross, near Torquay, and there carried out his classical investigations on the subject of ship resistance. His results were soon applied in practice by Scott Russell, Edward Reed and William Denny.

Froude left no account of how he arrived at his conclusions, but his approach can reasonably be described as follows.

When a ship model is towed in still water it is immediately obvious that:

(1) there is resistance to motion;

(2) a pattern of surface waves is produced both at an angle to the direction of motion and at right angles thereto. If the model is run at a series of steady speeds there is a wave pattern peculiar to each speed; and

(3) depending upon the speed, the model changes both draft and trim by comparison with the draft and trim at rest.

It is reasonable to deduce that there must be friction between the hull surface and the water in contact with it. It can also be inferred that the motion causes pressures between portions of the hull and the adjacent fluid, and further, that these pressures must cause the formation of waves. Clearly frictional and wave-making forces will absorb energy and their combined effect must be responsible for the resistance to motion.

We can assume that Froude tested geometrically similar models. Fig. 1 shows the measured resistances of three such models plotted to a base of speed.† The graphs are informative, but not illuminating.

Suppose now that we deduct from the total measured resistances the resistance due to skin friction and plot the remaining or residuary resistance for unit displacement to a base of speed divided by the square root of the length, or speed-length ratio. We now obtain Fig. 2, where to a first approximation the results appropriate to each model lie upon one single line. This diagram illustrates Froude's fundamental discovery. His basic assumptions are:

(1) The total resistance R_T of a ship's hull may be regarded as the sum of two components, R_F and R_R, the frictional and residuary resistances, where the frictional resistance is substantially independent of the shape of the body and where the residuary component is made up of wave-making and eddy resistances. It is also assumed that the two main component resistances can be treated separately and regarded as independent of each other.

(2) The Law of Comparison is generally valid, namely,

$$R_R \propto \Delta \text{ when } V \propto \sqrt{L} \text{ or } \frac{R_R}{\Delta} = f\left(\frac{V}{\sqrt{L}}\right)$$

where $R_R = R_T - R_F$, as defined in (1) above. L and Δ are respectively the length and displacement of the hull, and V is the speed. Froude tested planks of various lengths 19½ in deep and up to speeds of 10 ft per sec. He found that

$$R_F = f S V^n$$

where f is a numerical constant and S is the wetted area.

In the customary units R_F is in lb, S is in sq. ft, V is in knots, and $n = 1{\cdot}825$; then for salt water,

$$f = 0{\cdot}00871 + \left(\frac{0{\cdot}0530}{8{\cdot}8 + L}\right)$$

or for fresh water,

$$f = 0{\cdot}00846 + \left(\frac{0{\cdot}0516}{8{\cdot}8 + L}\right)$$

where L is in ft.

We can arrive at this result in another way—by dimensional analysis. If there is frictional resistance only,

$$\frac{R_F}{\frac{1}{2}\rho S V^2} = f_1\left(\frac{V L}{\nu}\right)$$

where ρ is the mass density and ν is the kinematic viscosity. If there is wave-making only,

$$\frac{R_W}{\frac{1}{2}\rho S V^2} = f_2\left(\frac{V}{\sqrt{gL}}\right)$$

where R_W is the resistance due to wave-making. For a surface ship,

$$\frac{R_T}{\frac{1}{2}\rho S V^2} = \Sigma K_m \left(\frac{V L}{\nu}\right)^m \Sigma K_n \left(\frac{V}{\sqrt{gL}}\right)^n = f\left(\frac{V L}{\nu}, \frac{V}{\sqrt{gL}}\right).$$

All that this equation tells us is that the total resistance is some function of the Reynolds number, $\frac{V L}{\nu}$, and the Froude number, $\frac{V}{\sqrt{gL}}$.

At this stage in the reasoning it is customary to adopt the Froude hypothesis that frictional and wave-making resistances are independent and can be considered separately, and therefore to write

$$\frac{R_T}{\frac{1}{2}\rho S V^2} = f_1\left(\frac{V L}{\nu}\right) + f_2\left(\frac{V}{\sqrt{gL}}\right).$$

We now know that Froude's Law of Comparison is not strictly correct. If a smooth model is tested, then retested with a roughened surface, the resistance is increased; but, more important for our present purposes, the wave configuration around the model is altered. This is a case where a change in the frictional resistance has had a pronounced effect upon the wave-making, and hence upon the residuary resistance.

Research has shown that frictional resistance is associated with the development of a boundary

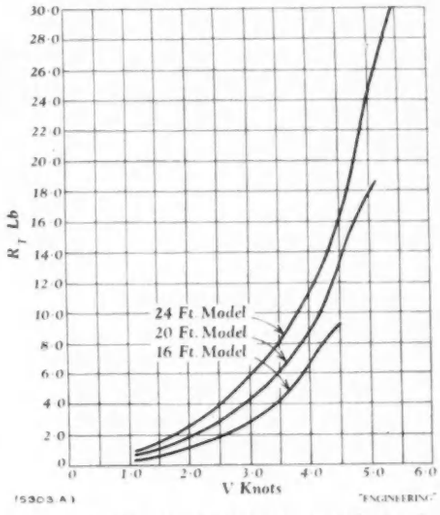


Fig. 1 Resistances of three geometrically similar models to a base of speed.

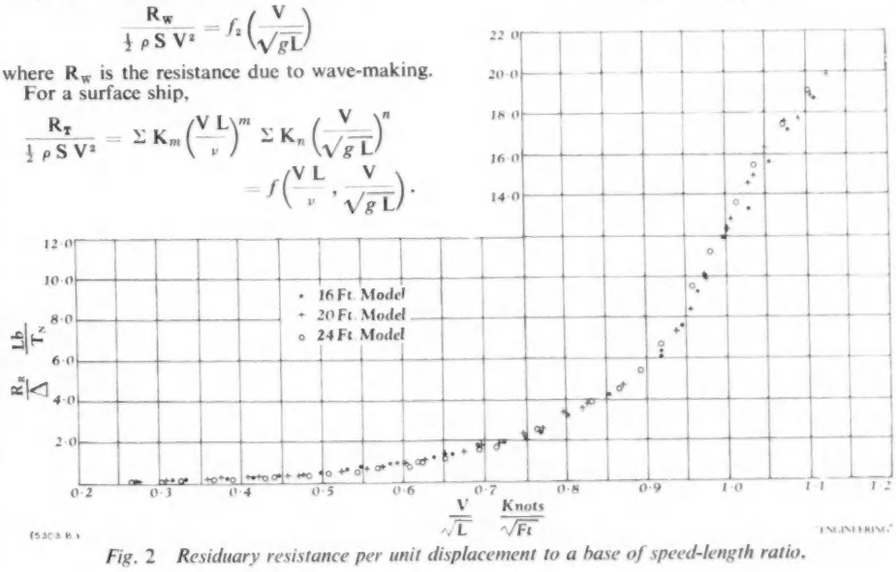


Fig. 2 Residuary resistance per unit displacement to a base of speed-length ratio.

* Paper read before Section G, British Association, in Glasgow on Monday, 1 September, 1958. The first part is published here; the second and concluding part will be published shortly.

† Conn, Lackenby and Walker, "B.S.R.A. Resistance Experiments on the 'Lucy Ashton'. Part II: The Ship Model Correlation for the Naked Hull Condition." *Trans I.N.A.* vol. 95, p. 350 (1953).

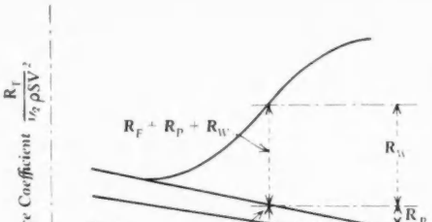


Fig. 3 The components of resistance due to motion.

layer around the hull surface and the thickness of this layer does not increase in a simple manner with increase of scale. Hence geometrically similar models cease to be geometrically similar when the thicknesses of the boundary layers are added to the form.

Froude's basic law postulates the similarity of wave systems generated by similar models at corresponding speeds, i.e., those speeds at which the speed-length ratio, or $V/\sqrt{L}$, is constant.

So far as the writer is aware, no tests have been made to confirm this similarity of wave systems. Nevertheless, the wave systems generated by geometrically similar models at corresponding speeds could be mapped accurately by the use of stereoscopic photography.

For a rigorous discussion of ship resistance the simple partitioning of the total resistance into residuary and frictional components is unsatisfactory. The modern treatment is as follows:

(*a*) *Wave-Making Resistance.*—This resistance is experienced by a vessel operating at or near the surface. It arises from the energy transferred by the ship to a wave system that accompanies and diverges from the hull. It can be treated as a problem in potential theory by the methods of classical hydrodynamics. The velocity potential must be written down in mathematical form after which the wave resistance in a perfect fluid can be calculated either by:

(1) integration over the hull surface of a pressure increment due to the wave motion;

(2) calculation of the energy transferred to the wave systems generated by the hull; and

(3) calculation of the forces experienced by the singularities chosen to represent the body.

(*b*) *Viscous Resistance.*—The total viscous resistance is made up of two components, frictional resistance, R_F, and a viscous pressure resistance, R_P. The former is the tangential and the latter is the normal component of the viscous resistance, so that the viscous resistance $R_V = R_F + R_P$.

Froude assumed that the frictional resistance of a vessel is the same as that of a flat plate having the same length and wetted surface. This is not exactly true, but the difference, known as the frictional form resistance, cannot be large for normal ship forms.

The viscous pressure resistance arises from changes in the pressure field around the vessel due to viscosity. These changes arise because of the gradual thickening of the boundary layer from bow to stern. They may be further increased by separation of flow.

The sum of the viscous frictional and pressure resistance is known in aeronautics as profile drag. The latter is, of course, a function of the Reynolds number and the location of transition, if any, from laminar to turbulent flow in the boundary layer.

Fig. 3 shows the subdivision of resistance components in diagrammatic form. The total specific resistance coefficient $R_T/\frac{1}{2}\rho S V^2$ is made up of:

(*a*) The skin friction R_F of the ship hull—the summation of all the tangential shear stresses over the hull surface.

(*b*) The flat-plate friction, R_{FO}—the summation of all the tangential shear stresses over a flat plate having the same length and surface area as the hull.

(*c*) The frictional form resistance—the amount by which the ship skin friction R_F exceeds the flat-plate friction, R_{FO}, due to the augmented velocities arising from form or shape.

(*d*) Due primarily to the boundary layer—a pressure resistance of viscous origin, R_P.

(*e*) The total viscous resistance, $R_{TV} = R_F + R_P$—commonly assumed to be a constant fraction of $R_{FO}/\frac{1}{2}\rho S V^2$.

(*f*) The wave resistance, R_W—from pressure due to the formation of waves at the free surface.

(*g*) The total resistance is

$$R_T = R_F + R_P + R_W.$$

In the same way the wave resistance R_W can be split up into components arising from

(i) Bow and stern patterns.
(ii) Entrance and run.
(iii) Parallel middle body.
(iv) Bow and stern interference.
(v) Interference of bow and stern with entrance and run.
(vi) Interference of entrance and run.

Where the parallel middle body is the portion of the ship in the midship region at which there is no change of shape, and the entrance and run are the shaped ends forward and aft of the parallel middle body. The first two terms are not oscillatory, but the other terms oscillate and their precise influence in any given case depends on the speed and shape of the hull.

Fig. 4 shows an ingenious form of presentation, devised by Professor E. V. Telfer, which depicts the value of specific resistance coefficient as a function of both the Reynolds number VL/ν and Froude number $V/\sqrt{gL}$. On this diagram are shown the specific resistance coefficients for a series of geometrically similar models,* also the latest internationally agreed turbulent skin-friction line for smooth surfaces,

$$C_F = \frac{R_F}{\frac{1}{2}\rho S V^2} = \frac{0{\cdot}075}{(\log R - 2)^2}, \text{ where } R = VL/\nu.$$

As a matter of interest, Froude's skin friction lines for various lengths of ship are also shown. These values contained unspecified allowances for the effect of roughness of surface, a fact which will be considered later.

PROPULSION

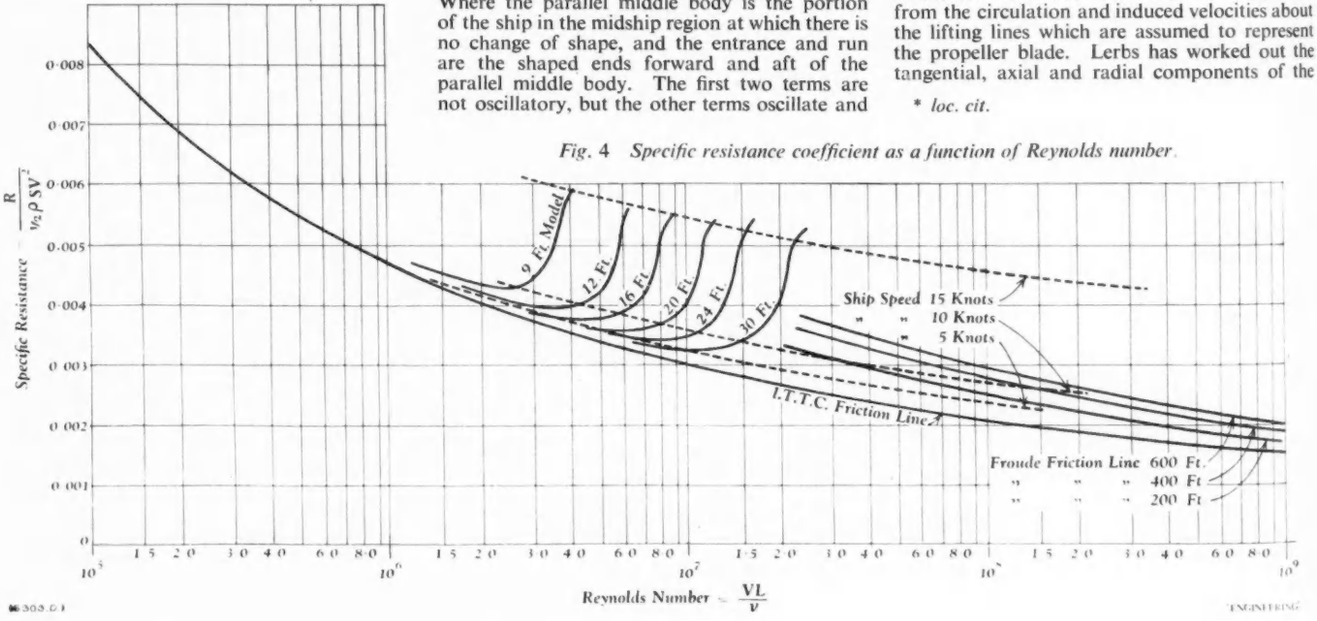
The first theoretical investigation of the screw propeller treated it as an actuator disc and dealt with considerations of axial momentum only. Modern theories consider a screw propeller as an assembly of the separate blade elements acting at their different distances from the axis of rotation. Allowance is made for interference between the blades, and the total thrust and torque are obtained by integration of the elementary thrusts and torques calculated for the several blade elements. Such treatments are based upon the application of aerofoil theory.

Unlike aerofoils, which are intended to set up a force perpendicular to the direction of relative motion, a screw propeller is designed to produce a force parallel to the direction of motion and thereby do work against the surrounding medium. The thrust of a propeller blade arises essentially in the same way as the lifting force on an aerofoil, the main difference being that owing to the simultaneous translation and rotation of the propeller, the blade elements advance in spirals instead of in straight lines. As in the case of aerofoils, the production of lift is accompanied by the shedding of vortices from the trailing edges and these vortices combine to stream from the extremities of the blades. Those arising from each blade root rotate in the same direction as the blades and combine to form a "boss vortex"; those arising from the tips form a spiral enclosing the whole mass of fluid which passes through the propeller disc. This mass of fluid is in both translational and rotational motion. The former is a necessary consequence of thrust, but the rotational motion is an unavoidable evil and the kinetic energy due there to should be reduced to a minimum.

In propeller theory, use is made of the Kutta-Jowkowski law and the thrust is calculable from the circulation and induced velocities about the lifting lines which are assumed to represent the propeller blade. Lerbs has worked out the tangential, axial and radial components of the

* *loc. cit.*

Fig. 4 Specific resistance coefficient as a function of Reynolds number.



induced velocity as functions of the radius for 3, 4 and 5-bladed propellers. With a given circulation, these components can be integrated radially for any arbitrary pitch distribution.

Lerbs has also evaluated various cases, both for free-running and for wake-adapted propellers, the latter being designed to operate efficiently in the wake behind a ship hull, where the inflow velocity distribution varies both radially and circumferentially. The problem of the optimum propeller is, for a given power, advance speed, rotational speed and wake distribution, to determine the circulation distribution which will give the maximum value of useful, or thrusting, power.

In practice, these elaborate and tedious calculations are rarely, if ever, undertaken. The designer makes use of the many model propeller test results now available, where the parameters have been systematically varied and from which he can work out quickly the optimum diameter, pitch and blade area.

To investigate the efficiency of propulsion, self-propulsion tests are made. The experimental results provide figures for the propulsive efficiency, usually defined as quasi-propulsive efficiency

$$= \frac{\text{effective or tow rope horsepower}}{\text{shaft horsepower at tail end}}$$

where effective horsepower = resistance × speed × numerical constant, and shaft horsepower at the tail end is the power delivered to the propeller. According to the Froude method of analysis, this efficiency is split up into components, viz.,

$$\text{QPC} = (1 + w)\,(1 - t)\,(\text{open-propeller efficiency})\,(\text{relative rotative efficiency})$$

Where QPC is the quasi-propulsive coefficient; $(1 + w)$ is the wake factor, and takes account of the fact that the propeller is working in water which has already been set in motion by the passage of the ship; $(1 - t)$ is the thrust deduction factor, and takes account of the fact that the presence of the propeller adds to the resistance of the hull; the two remaining factors take account of the differing efficiencies of a propeller when tested separately and behind a hull.

In the case of single-screw ships, these tests are commonly made with the rudder fitted. For twin-screw ships, the twin-screw bossings or brackets are fitted. The optimum position for these appendages can be found by experiment, so that the bossings may be placed along the natural lines of flow. On the other hand, it is sometimes found that higher propulsive efficiencies can be obtained with the bossings placed at an inclination to the natural line of flow, but much depends upon the circumstances of each particular case and whether the propellers rotate inward or outward over top dead centre.

It cannot be too strongly emphasised that the optimum hull is not that which has the lowest resistance, but that which requires the minimum horsepower for propulsion, at and about the designed service speed. A hull may have a low resistance, but have after-body sections or bossing webs which are not conducive to a good flow of fluid into the propeller disc. To investigate the propulsion qualities of a vessel with any attempt at completeness it is therefore necessary to carry out:

(1) resistance tests with the naked hull;

(2) resistance tests with the hull plus any appendages which affect the propulsive qualities, such as bossings; and

(3) self-propulsion tests.

Further, the optimum hull has the minimum increase of resistance in waves and maintains a steady course with the minimum use of helm.

Propellers for high-speed vessels present special difficulties, of which the greatest is, perhaps, cavitation. Cavitation may be defined as the formation and collapse of cavities in a stream of flowing liquid which results from pressure changes within the stream caused by changes in the velocity of flow. A cavity may be expected to form at every point in the liquid where the local pressure is reduced to that of the vapour pressure of the liquid at the temperature of the stream. Collapse of such a cavity will start when the pressure of the surrounding liquid becomes greater than the vapour pressure, as, for example, if the cavity is transported by the liquid into a region of higher local pressure.

In the case of a fast vessel, where both advance and rotational speeds are high and the thrust is large, the suction pressures on the backs of the blades become so low that cavitation may be unavoidable.

Thanks to the development of screw-propeller theory, and to experimental work in cavitation tunnels, the design of blade-section shapes has made great advances so that much greater thrusts per unit area can now be obtained than in the past.

POWER PREDICTION

For many years the practice has been to tow a model of the hull under investigation, measure the total resistance, subtract the frictional resistance according to Froude's values, take the remaining or residuary resistance up to the full scale according to the Law of Comparison, and add to this the ship frictional resistance, again according to Froude's values.

But Froude's values for ship frictional resistance include an empirical but unspecified allowance for the effect of hull roughness, and ship hulls have become much smoother since Froude's time, due to the adoption of welding. The decrease in structural roughness has been marked and it is probably true to say that greater efforts are now being made to secure a smooth painted surface on the shell plating.

Froude's treatment of frictional resistance is gradually being discarded in favour of a more rational treatment based upon a smooth curve of turbulent, frictional resistance coefficient to a base of the Reynolds number, as shown in Fig. 4.

It is common knowledge that power predictions based on model experiment results have, of recent years, been far from accurate, for all types of ships. The difficulties are many. The experimenter has to contend with:

(1) *Resistance Tests.*—Laminar flow and the consequent necessity for turbulence stimulation, the possibility of separation of flow around full forms, roughness, blockage.

(2) *Appendages.*—Scale effect on rudders, bossings and brackets.

(3) *Self-Propulsion Test.*—Scale effect on wake, thrust deduction, relative rotative efficiency, open water efficiency and quasi-propulsive efficiency, also on r.p.m. of the propeller. Deformation of propeller blades under load, either in bending and/or twisting, cavitation and air drawing effects, laminar flow on propeller blades, blockage.

(4) *Open-Water Propeller Tests.*—Inaccuracy of manufacture, roughness, laminar flow, blade deformations.

Hence when ship powers are predicted from the results of model resistance and self-propulsion experiments, it is reasonable to expect that an overall empirical factor is necessary to take account of these many factors. It is still desirable, however, that the problem of extrapolation to the full scale be made on a sound scientific basis. One such basis is as follows

As is shown on Fig. 5, the residuary component curve for R_R is moved bodily in the direction of increasing Reynolds number, parallel to a basic friction line. (It is often raised vertically at the ship Reynolds number by some such proportion as 0·0004.)

It seems reasonable to take the component R_R as that which must be scaled up according to Froude's Law of Comparison. If complete turbulence has been achieved on the model scale, the ship resistance should be capable of fairly accurate assessment by this means, provided that the hull is smooth. We are uncertain regarding an allowance for ship roughness and must determine this. The practical problem is the prediction of shaft horse-power, SHP, at the tail end.

The quasi-propulsive coefficient, QPC, is measured directly in a model test, i.e.,

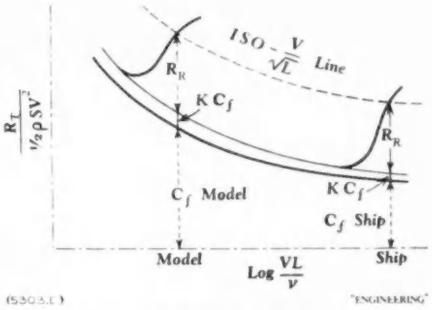


Fig. 5 Extrapolation diagram.

$$(\text{QPC}) = \frac{\text{resistance} \times \text{speed}}{2\pi \times \text{torque} \times \text{r.p.m.}}.$$

By Froude's method of analysis, we can also write

$$\text{QPC} = (1 + w)\,(1 - t)\,\eta_0 r$$

in the usual notation.

Since there is certain to be a scale effect on wake as between model and ship, and since it is known that the numerical value of the open water efficiency of a propeller is dependent upon the size of the propeller model, it is reasonable to suspect scale effect in the QPC.

It is exceedingly difficult to arrive at any numerical assessment of the scale effect. However, there are a wealth of accurate trial data available with which to investigate the problem.

By definition,

$$\text{QPC} = \text{EHP/SHP},$$

so that

$$\text{SHP} = \text{EHP/QPC}$$

It is usual to write

$$\text{SHP} = \frac{\text{EHP} + \text{percentage allowance}}{\text{QPC}}$$

thus crediting whatever discrepancies that may arise to the EHP, that is, to the hull resistance.

Suppose, however, that we write

$$(\text{SHP})_{ship} = \frac{\text{EHP}\,(1 + x)}{\text{QPC}\,(1 + y)}$$

where x is the fractional scale effect on hull resistance and y is the fractional scale effect on quasi-propulsive efficiency. Then if we take two values of accurately determined SHP, say at the service speed and another speed close thereto, we can work out values of x and y.

The process can be repeated for another pair of speeds and, of course, for other vessels of similar (and other) types.

All the above treatment assumes:

(*a*) The EHP values are based on a rational skin friction formulation and not on Froude's skin friction values, since the latter contain an unspecified allowance for roughness.

(*b*) Complete turbulence has been achieved in the model tests.

(*c*) The self-propulsion tests have been made at the ship self-propulsion point, with no overload allowance.

(*d*) Complete turbulence has been achieved over the propeller blades in both behind and open conditions.

(*e*) Wind and steering effects have been eliminated from the full-scale SHP figures.

To be continued

PLA HARBOUR RADAR

The first harbour radar for the projected Thames Navigation Service will be a Decca harbour radar type 33, for which a contract has just been placed by the Port of London Authority with Decca Radar Limited, Albert Embankment, London, S.E.11. The radar station will be at Gravesend. The type 33 equipment is a high-definition X-band equipment using an aerial of 6 ft span. There are two separate transmitters and receivers with remotely controlled change-over switching arrangements. The 15 in diameter display is of the fixed-coil type.

Continuing **Design**

ELECTRICAL VECTOR-LOCI DISPLAY APPARATUS*

By P. Strange, B.SC.†

VECTOR loci provide a very interesting and convenient method for studying behaviour of electrical machines and networks. In the past electrical loci have usually been confined to simple linear and circular loci, but many other different classes and shapes may be encountered in the field of electrical engineering. Indeed, the study of electrical machinery alone provides an astonishing variety of different loci.

Since 1900 many papers on loci have been published, both from the theoretical and the practical aspects, the two principal authors being Bloch[1] and Michael.[2] Although a wide interest in the subject has been shown by Swiss and German engineers, it appears that no significant paper or book on loci has yet been published in English. A brief introduction has been given by Hague[3] but much work remains to be done in this important field. The purpose of this short paper is to describe an apparatus for the display of loci and to illustrate some of the many forms which have been obtained by means of the apparatus.

CLASSES OF LOCI

As far as loci in electrical engineering are concerned a vector locus can be defined as the curve described on a complex plane by the extremity of a vector when, by some variable parameter, the vector is caused to alter in magnitude and direction with respect to some fixed datum. In electrical circuitry for example, the vector representing current in an alternating current circuit can be made to vary in magnitude and direction by a change in either the frequency of the exciting supply voltage or by a change in one of the circuit components. The study of vector loci can be greatly simplified by the development of suitable mathematical methods. Many loci encountered in electrical engineering are of a high order, i.e., cubics and quartics, which are not easily studied by conventional Cartesian geometry.

It is convenient and possible to divide electrical circuit loci into four groups, as follows:—

(1) Loci of impedances and admittances of circuits fed at *either* constant voltage *or* constant current when one or other of the circuit components is changed, the supply frequency being constant.

(2) Similar loci when *constant* linear passive networks are fed at variable frequency.

(3) Similar loci when constant linear *active* networks are fed at variable frequency.

(4) Loci of the zeros and poles of a function as coefficients in the function are varied.

Usually loci encountered in electrical or electro-mechanical systems fall into one of the first three groups. The fourth group is much more general in scope.

Into the first group fall the loci of electrical machinery, e.g. the well-known circle diagram of the induction motor and the higher order curves of machines with phase advancers. The loci in this group have no restrictions in the complex plane and are thus quite general.

Into the second group fall the loci of linear passive network theory. The loci of such net-works are restricted by stability and realisability criteria.

Into the third group fall the important loci of feed-back circuits and control systems. The stability and performance of such systems are conveniently studied by means of loci, for example, the well-known Nyquist diagram.

Although the loci of the fourth group are strictly of mathematical interest, the results obtained from their study are becoming widely used in the design of control systems, as for instance the root-locus[4] method.

The study of the loci of electrical machinery is well advanced and has been developed over the last 50 years, whereas the study of the loci of control systems and networks is a much more recent development. Since the loci of all four groups have a common mathematical basis, many of the theorems which have been developed for those of group (1) are equally applicable to the study of control system loci.

GENERAL THEORY

Any electrical machine or network can be analysed on either the loop or the junction basis. For the loop solution it is convenient first to convert all the sources to potential equivalents. Similarly in the case of junction solutions all sources are first converted to current equivalents. However, the general form of the two solutions will be identical; i.e. a set of simultaneous equations:—

$$\left.\begin{aligned} a_{11}\,\mathrm{T}_1 + a_{12}\mathrm{T}_2 + \ldots\ldots a_{1m}\mathrm{T}_m &= \mathrm{S}_1 \\ a_{21}\,\mathrm{T}_1 + a_{22}\mathrm{T}_2 + \ldots\ldots a_{2m}\mathrm{T}_m &= \mathrm{S}_2 \\ a_{m1}\mathrm{T}_1 + a_{m2}\mathrm{T}_2 + \ldots\ldots a_{mm}\mathrm{T}_m &= \mathrm{S}_m \end{aligned}\right\} \quad . \quad (1)$$

with the symbols as follows:—

Symbol	Loop analysis	Junction analysis
m	Number of independent loops	Number of non-datum junctions
S_p	Potential source in loop p	Current source at junction p
T_q	Current response in loop q	Potential response at junction q
a_{pq}	Co-pedance Z_{pq}	Committance Y_{pq}

Equation (1) may be written in the matrix form;

$$\begin{bmatrix} \mathrm{S}_1 \\ \mathrm{S}_2 \\ \\ \mathrm{S}_m \end{bmatrix} = \begin{bmatrix} a_{11}\,a_{12} \ldots\ldots a_{1m} \\ a_{21}\,a_{22} \ldots\ldots a_{2m} \\ \\ a_{m1}a_{m2} \;\ldots\; a_{mm} \end{bmatrix} \begin{bmatrix} \mathrm{T}_1 \\ \mathrm{T}_2 \\ \\ \mathrm{T}_m \end{bmatrix}$$

i.e.

$$[\mathrm{S}_r] = [a_{rs}]\,[\mathrm{T}_r]$$

with

$$r,\ s = 1 \text{ to } m.$$

Now if the S's are constant and known, then

$$[\mathrm{T}_r] = [a_{rs}]^{-1}\,[\mathrm{S}_r]$$

The inverse of $[a_{rs}]$ is given by

$$\frac{1}{sr\ |a|}\,[\mathrm{A}_{sr}]$$

where $[\mathrm{A}_{sr}]$ is the adjoint of $[a_{rs}]$ and $|a_{rs}|$ is the determinant of the square matrix $[a_{rs}]$.

Thus,

$$[\mathrm{T}_r] = \frac{1}{|a_{rs}|}\,[\mathrm{A}_{sr}]\ [\mathrm{S}_r].$$

If the a's are functions of a real variable t, which may for instance represent frequency in a variable frequency network or slip in the case of an electrical machine, then the general form of the T's can be written

$$\mathrm{F}(t) = \frac{\mathrm{P}(t)}{\mathrm{Q}(t)}$$

i.e.,

$$\mathrm{F}(t) = \frac{\mathrm{B}_0 + \mathrm{B}_1 t + \mathrm{B}_2 t^2 + \ldots\ldots \mathrm{B}_p t^p}{\mathrm{C}_0 + \mathrm{C}_1 t + \mathrm{C}_2 t^2 + \ldots\ldots \mathrm{C}_q t^q}$$

where the B's and C's can be real, complex or imaginary coefficients; thus,

$$\mathrm{F}(t) = \frac{(\mathrm{B}_0' + \mathrm{B}_1' t + \ldots \mathrm{B}_p' t^p) + j(\mathrm{B}_0'' + \mathrm{B}_1'' t + \ldots \mathrm{B}_p'' t^p)}{(\mathrm{C}_0' + \mathrm{C}_1' t + \ldots \mathrm{C}_q' t^q) + j(\mathrm{C}_0'' + \mathrm{C}_1'' t + \ldots \mathrm{C}_q'' t^q)}$$

and, rationalising,

$$\mathrm{F}(t) = \frac{\mathrm{B}'(p)\,\mathrm{C}'(q) + \mathrm{B}''(p)\,\mathrm{C}''(q) + \mathrm{B}''(p)\,\mathrm{C}'(q) - \mathrm{B}'(p)\,\mathrm{C}''(q)}{\{\mathrm{C}'(q)\}^2 + \{\mathrm{C}''(q)\}^2} \quad . \quad (2)$$

As t is varied from $+\infty$ to $-\infty$, then the extremity of the vectors corresponding to individual values of t will describe a locus on the complex plane.

The degree in t of the numerator of equation (2) is $(p + q)$ and that of the denominator $2q$. The degree of the locus is thus either $(p + q)$ or $2q$ depending whether $(p + q) > 2q$ or $2q > (p + q)$.

The general form of the loci up to and including the bicircular quartic are given below in which sinors are denoted by bold-face type (Clarendon), e.g. **A**, **B**, **C**, etc., and complex operators are denoted by Script, e.g. $\mathscr{A}$, $\mathscr{B}$, $\mathscr{C}$, etc.

Fig. 1 Block diagram of locus display apparatus.

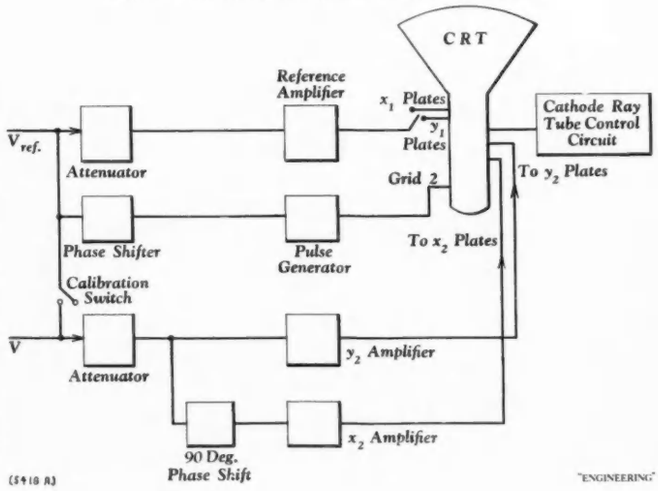
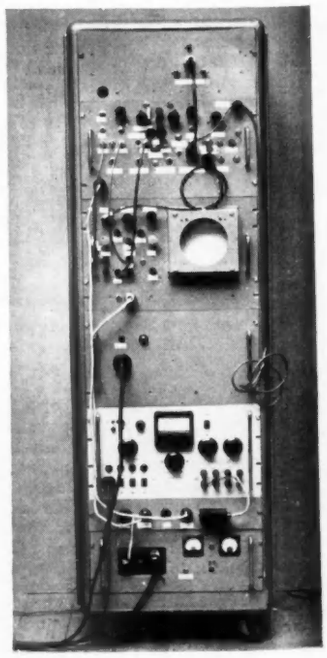


Fig. 2 Locus display equipment.



* Young Engineers' Paper read before Section G, British Association, at Glasgow, on Monday, 1 September, 1958.

† Formerly of the Electrical Engineering Department, The University, Nottingham.

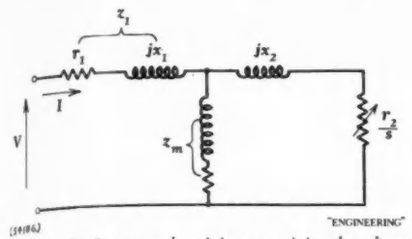


Fig. 3 R-C network giving semicircular locus shown in Fig. 4.

Fig. 4 Locus of output voltage $\mathbf{V}_{out}$ *of Fig. 3, the input reference voltage* $\mathbf{V}_{in}$ *being in y-direction.*

Linear locus.—

$$\mathbf{L} = \left(\frac{\mathscr{A} + \mathscr{B}\,t}{\mathbf{P} + \mathbf{Q}\,t}\right)\mathbf{1}$$

where **1** is the unit operator and P and Q are real numbers.

Circular locus.—

$$\mathbf{C} = \left(\frac{\mathscr{A} + \mathscr{B}\,t}{\mathscr{P} + \mathscr{Q}\,t}\right)\mathbf{1}$$

where $\mathscr{P}$ and $\mathscr{Q}$ are complex.

Conic loci.—

$$\mathbf{C}_0 = \left(\frac{\mathscr{A} + \mathscr{B}t + \mathscr{C}\,t^2}{\mathbf{P} + \mathbf{Q}\,t + \mathbf{R}\,t^2}\right)\mathbf{1}$$

where P, Q and R are real numbers.

$\mathbf{C}_0$ = hyperbola when $\mathbf{Q}^2 > 4\,\mathbf{R}\,\mathbf{P}$

$\mathbf{C}_0$ = parabola when $\mathbf{Q}^2 = 4\,\mathbf{R}\,\mathbf{P}$

$\mathbf{C}_0$ = ellipse when $\mathbf{Q}^2 < 4\,\mathbf{R}\,\mathbf{P}$

Circular cubic loci.—

$$\mathbf{C}_u = \left(\frac{\mathscr{A} + \mathscr{B}\,t + \mathscr{C}\,t^2}{\mathscr{P} + \mathscr{Q}\,t}\right)\mathbf{1}$$

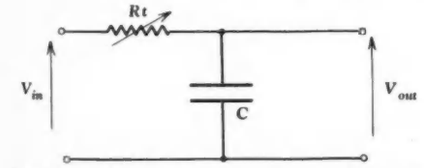
where $\mathscr{P}$ and $\mathscr{Q}$ are complex.

Bicircular quartic loci.—

$$\mathbf{Q} = \left(\frac{\mathscr{A} + \mathscr{B}\,t + \mathscr{C}\,t^2}{\mathscr{P} + \mathscr{Q}\,t + \mathscr{R}\,t^2}\right)\mathbf{1}$$

where $\mathscr{P}$, $\mathscr{Q}$, $\mathscr{R}$ are complex. The scale of t may be either linear or some function of another variable.

The construction of vector loci, particularly those of high order is greatly simplified by the use of a number of theorems which enable one to draw the tangents to the curve at any value of t round the curve.



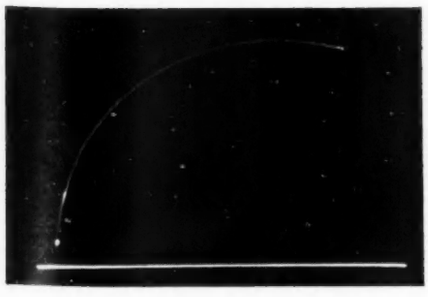


Fig. 7 (left) Single-phase equivalent circuit of a single-cage 3-phase induction motor.

Fig. 8 (below left) Locus of stator current **I** *of the induction motor of Fig. 7, reference voltage* **V** *being in y-direction.*

DISPLAY APPARATUS

Theory of Operation.—For the experimental recording of vector loci it is convenient to employ some form of display apparatus which will show the reference axis as a straight line and the extremity of the vector as a spot on a cathode-ray tube.

A number of papers have been given describing such apparatus, the basic principle being similar in each case.[5, 6, 7]

All the vector quantities to be displayed are assumed to be voltages and sinusoidal in waveform. This latter condition is very important since the theory of operation depends upon the assumption that the vectors may be written in the form $v = \mathrm{V}\sin(\omega t + \phi)$.

Consider a sinusoidal reference voltage $v_r = \mathrm{V}_r \sin \omega t$ in which the angular frequency $\omega = 2\pi f$. A sinusoidal voltage displaced in phase from v_r by an angle ϕ can be written as:—

$$v = \mathrm{V}\sin(\omega t + \phi).$$

If v is now shifted in phase by 90° or $\pi/2$ radians, then

$$v' = \mathrm{V}\sin(\omega t + \phi + \pi/2)$$
$$= \mathrm{V}\cos(\omega t + \phi).$$

Suppose that the voltage v' is applied to the x-deflection plates of a cathode-ray tube and the voltage v applied to the y-deflection plates, the resultant displacement of the spot on the screen will be given by

$$\mathbf{D} = \mathrm{K}\,\mathrm{V}\{\cos(\omega t + \phi) + j\sin(\omega t + \phi)\}$$

where K is the deflection per volt.

Thus $\mathbf{D} = \mathrm{K}\,\mathrm{V}\,\varepsilon^{j\theta}$

where $\theta = \tan^{-1}\left\{\dfrac{\sin(\omega t + \phi}{\cos(\omega t + \phi}\right\}$

$\theta = (\omega t + \phi)$

and therefore $\mathbf{D} = \mathrm{K}\,\mathrm{V}\,\varepsilon^{j(\omega t + \phi)}$

The spot will thus describe a circle of radius K V once per cycle of the supply frequency. Also, at time $t = 0$ in each cycle, the spot will be displaced from the x-axis by an angular displacement ϕ. Thus, if a brightening pulse is applied to the cathode-ray tube at time $t = 0$, a bright spot will be produced the distance of which from the centre of the tube is proportional to V and the angular displacement from the x-axis is the phase angle ϕ. By arranging that the trace is brightened at the commencement of every cycle of the reference voltage, the spot on the screen will appear continuously bright at its correct position.

Description of Apparatus.—Apparatus described by earlier writers has suffered from the disadvantage of either too complex circuitry or from over-simplicity and a consequent loss in accuracy. The requirements are that the display shall consist of the reference axis, shown as a straight line through the origin, and a spot to mark the extremity of the vector to be exhibited. In order to display both the vector and the reference axis together, some form of switching must be employed so that the reference axis is displayed for almost the full cycle of the supply frequency; the extremity of the vector is then displayed for only a very short time while the reference voltage passes through zero.

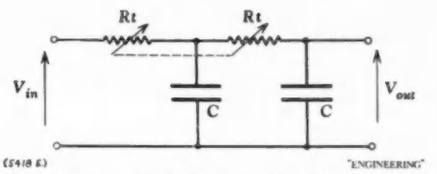


Fig. 5 Cascade R-C network giving cardioid locus shown in Fig. 6.

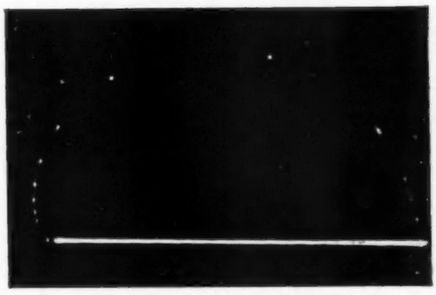


Fig. 6 Locus of output voltage $\mathbf{V}_{out}$ *of Fig. 5, input reference voltage* $\mathbf{V}_{in}$ *being in y-direction.*

The circuitry can be considerably simplified by the use of a double-gun cathode-ray tube, one beam displaying the reference axis, the other displaying the extremity of the vector.

A block diagram of the apparatus is shown in Fig. 1. The reference voltage v_r is fed through a switched attenuator to the reference axis deflection amplifier. This amplifier has a low-gain push-pull stage, the output of which can be switched to either the x- or y-deflection plates.

The reference voltage is also fed to a square-wave generator through a resistance-capacitance phase-shifting circuit, the purpose of which will be described later. The square-wave generator is essentially an a stable cathode-coupled multivibrator having a natural frequency much lower than the lowest frequency to be displayed. An input voltage exceeding about 3 volts will synchronise the output, and the resultant output is an accurate square wave of the same frequency and phase as the input sine wave. Preset controls enable the mark-space ratio to be set at unity.

The square-wave is next differentiated and

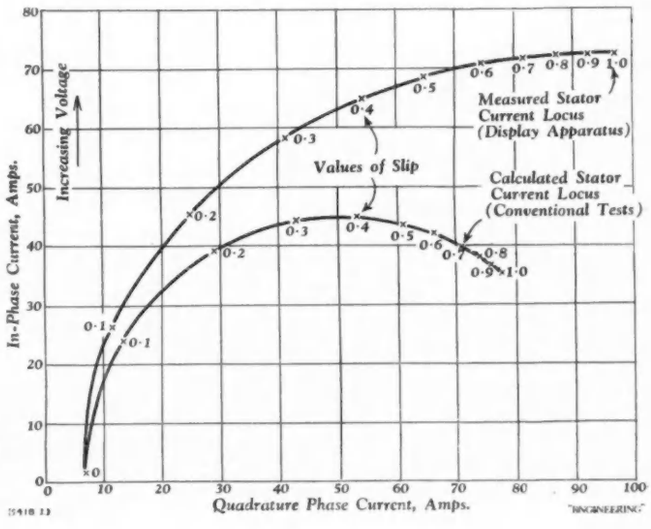


Fig. 9 (right) Comparison of stator current loci of induction motor from conventional test calculations and from display apparatus.

applied to a monostable multivibrator. The resultant output is a narrow square pulse at the instant the square wave passes through zero and hence at the instant the reference voltage passes through zero. A switch selects the pulse duration and hence the size of the spot on the cathode-ray tube; the pulse width is variable from about 10 microseconds to 200 microseconds. This output pulse is fed to the grid of the cathode-ray tube through a potentiometer, which provides a spot brightness control, and a condenser, since the grid is normally at about − 2,000 volts with respect to earth. The cathode-ray tube is normally biased off, the positive pulse switching on the beam for the duration of the pulse.

The input voltage v is fed in through a switched attenuator to the y_2-deflection amplifier and to the x_2-deflection amplifier by a phase-shifting circuit to give a lag of 90°. The phase-shifter for constant frequency operation is a simple Miller integrator which, apart from giving 90° phase lag, serves to smooth out any harmonics on the input signal. Considerable care must be taken in the design of the x_2- and y_2-deflection amplifiers. These must introduce no phase shift over the operating range and must be closely linear in operation. They must also be capable of giving a deflection of at least two diameters of the cathode-ray tube screen. Three-stage direct-coupled amplifiers with negative feedback are used, the linearity and phase-shift being easily checked by observing the circle on the screen for an input of v with the brightness control turned up.

The cathode-ray tube circuitry and power supply are quite conventional, the tube being of the long-persistence type. Independent brightness controls for each half of the tube are provided. Most recordings of loci are done photographically and hence it is convenient to use the reference line as a calibration scale. Before each test the apparatus is calibrated by applying a known voltage to both the inputs. The deflection due to v is then adjusted to give the same deflection as that due to v_r by means of a potentiometer circuit and the input attenuator readings are noted. A relationship is thus established between the two deflections.

For the study of machines it is usual to have a frequency-selective amplifier in the input of v in order to remove any harmonics due to saturation of iron paths. The additional phase-shift introduced by the frequency selective amplifier is corrected by means of the phase-shift circuit in the pulse generator input. This is conveniently done in the calibration procedure by adjusting the spot to lie on the reference line.

The apparatus as described is suitable for fixed-frequency loci only, due to the nature of the phase-shift circuit the attenuation of which varies with frequency. Suitable networks have been designed the phase difference of which is 90° over a 100 : 1 frequency range and these will enable the apparatus to be used for servo and network loci. It is hoped to describe these elsewhere at a later date.

By careful design and setting up, the apparatus is capable of magnitude measurements with a maximum error of about 3 per cent of full-scale and phase-angle measurements with an error of ± 3° depending on the spot and screen diameter.

Automatic calibration of the trace in terms of the independent parameter can be accomplished by stopping the locus at various fixed values of the parameter, and producing bright spots on the trace at these values.

In the case of electrical machines, the photographed locus can be calibrated manually in terms of slip by recording the motor current and speed on a two-channel pen recorder as the locus is traced on the cathode ray tube. A graph of slip against current enables the locus to be calibrated.

Fig. 2 illustrates the display equipment as it has recently been rebuilt.

EXAMPLES

Networks.—A simple example of a locus of the constant-frequency group is described by the output voltage of the simple series resistance-capacitance integrator network, Fig. 3.

The voltage V_{in} is connected to the reference input terminals, V_{out} to the vector input terminals.

The transfer function of the simple integrator circuit is given by:—

$$(\mathbf{V}_{out}/\mathbf{V}_{in}) = \mathbf{1}/(1 + j\,\omega\,\mathrm{R}\,\mathrm{C})$$

and if R is a linear function of a parameter t, then

$$(\mathbf{V}_{out}/\mathbf{V}_{in}) = \mathbf{1}/(1 + j\,\omega\,\mathrm{R}\,t\,\mathrm{C})$$

which is of the form

$$\mathbf{C} = \frac{1}{\mathscr{A} + \mathscr{B}\,t}$$

where

$$\mathscr{A} = 1$$
$$\mathscr{B} = j\,\omega\,\mathrm{R}\,\mathrm{C}.$$

The locus of $\mathbf{V}_{out}$ as the resistance is varied from 0 to + ∞ is the inverse of a straight line not passing through the origin and is thus a circle passing through the origin.

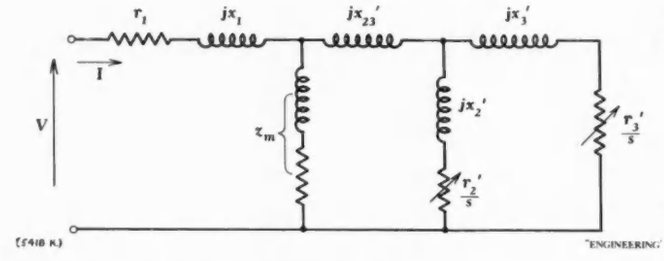


Fig. 10 (left) Single-phase equivalent circuit of a double-cage 3-phase induction motor.

Fig. 11 (right) Stator current locus for the double-cage motor of Fig. 10.

Fig. 4 shows the locus of $\mathbf{V}_{out}$ as t is varied from 0 to + ∞ the dots indicating various values of t. The part of the circle not shown occurs for negative values of t.

When two similar integrator circuits are connected in cascade, as in Fig. 5, a locus is obtained which is the square of a circle passing through the origin and is in fact a cardioid, as shown in Fig. 6.

$$\text{i.e.} \quad \left(\frac{\mathbf{V}_{out}}{\mathbf{V}_{in}}\right) = \left(\frac{1}{1 + j\,\omega\,\mathrm{R}\,\mathrm{C}\,t}\right)\left(\frac{1}{1 + j\,\omega\,\mathrm{R}\,\mathrm{C}\,t}\right)$$

$$\text{i.e.} \quad \mathbf{C} = \left(\frac{1}{\mathscr{A} + \mathscr{B}\,t}\right)^2 \mathbf{1}$$

Fig. 6 shows the corresponding locus of $\mathbf{V}_{out}$ as t is varied from 0 to + ∞.

Electrical Machines.—Whereas the locus of a network, however complex, can be calculated on paper, it is extremely difficult to do for the characteristics of a machine if the secondary effects such as saturation are taken into accouut. It is therefore in the study of electrical machines that the display equipment proves of great advantage. Since the complete current locus of a machine can be photographed in one or two seconds, it is possible to test the machine throughout its full range and it overloads without excessive overheating.

The equivalent circuit for one phase of a balanced three-phase wound-rotor induction motor as obtained from the normal no-load and short circuit tests is shown in Fig. 7. The stator input current is given by:—

$$\mathbf{I} = \left[\frac{\{r_2 + (z_m + j\,x_2)\,s\}}{r_2\,(z_1 + z_m) + \{z_1(z_m + j\,x^2) + j\,x_2\,z_m\}\,s}\right]\mathbf{V}$$

and is of the form

$$\mathbf{C} = \left(\frac{\mathscr{A} + \mathscr{B}\,t}{\mathscr{P} + \mathscr{Q}\,t}\right)\mathbf{1}$$

where $t = s$
$\mathscr{A} = r_2$
$\mathscr{B} = (z_m + \mathrm{j}\,x_2)$
$\mathscr{P} = r_2\,(z_1 + z_m)$
$\mathscr{Q} = \{z_1\,(z_m + j\,x_2) + j\,x_2\,z_m\}$.

Hence the locus of the stator current as the slip is varied is a circle.

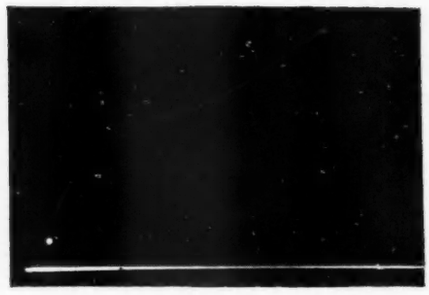
However, the current locus is circular only if the assumption of constant circuit parameters is made. Apart from variations due to temperature rise the various parameters may be expected to change with load.

Tests were made on a 5 h.p. three-phase wound-rotor induction motor, and Fig. 8 shows the recorded current locus on this machine. Fig. 9 shows the circle diagram as obtained from the conventional tests, together with the locus actually measured at full-rated volts. This serves to show the considerable divergence in results which can be expected at high values of slip.

As a further example, the equivalent circuit per phase of the double-cage induction motor is shown in Fig. 10. It can be readily deduced that the current locus will consist of the sum of two circular loci, one circle for the inner cage and one for the outer cage. Fig. 11 shows a typical stator-current locus for such a machine.

CONCLUSIONS

The apparatus described is a useful instrument for the study of second-order effects in electrical machines. Many tests can be performed quickly without overheating the machine. Accuracy is quite sufficient for the majority of tests, the resultant photographs being calibrated individually.



The addition of wide-band phase-shift networks will make possible the recording of servo system loci.

Acknowledgments.—The work described forms part of the author's post-graduate research, initiated and supervised by Professor J. E. Parton of the University of Nottingham. Awards were received from the University of Nottingham and from the British Thomson-Houston Company Limited, Rugby. The author is also indebted to Dr. W. J. Gibbs, of the above company, and to Professor B. Hague of the University of Glasgow for several helpful discussions.

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[7] E. R. Laithwaite, C. Cowell and W. G. Phillips, "A Method of Displaying Vectors on a Cathode-Ray Tube," *Proc. I.E.E.*, vol. 101, No. 129, pp. 140-144, May 1954.

Book Reviews

THINKING ABOUT DRAWING

Handbook of Layout and Dimensions for Production. By HYMAN H. KATZ. *The Macmillan Company*, 60 *Fifth Avenue*, *New York* 11, *N.Y.*, *U.S.A.* (15 dol); and *The Macmillan Company*, 10 *South Audley Street*, *London*, *W.1.* (87*s.* 6*d.*)

Thoughtful comments enrich this book. "Engineering Drawing is a universal language based on the science of descriptive geometry" turned up first, followed by: "The detail drawing is critically important because when it is released for manufacture it becomes a legal document, intended to be capable of only a single interpretation." These seemed a good start, showing qualities which, if maintained throughout, would justify its relatively high price.

A more careful reading confirmed the impression, though there is some padding. There are plenty of books dealing with engineering drawing as seen and practised in a technical college, but all too few which reflect the realistic atmosphere and severe discipline of good engineering design and manufacture. Starting with an introduction which gives a very good picture of the various activities and responsibilities of a drawing office and in the development of a design, the author goes through the stages of preliminary sketches, accurate geometrical layout, descriptive geometry, dimensioning, and the product drawings. Tolerances and limits for interchangeable assembly and batch manufacture, and jig and tool drawings follow. The emphasis throughout is that drawing is a language, a medium for the transmission of an idea, always a means to an end—the satisfactory manufacture of the hardware—never an end in itself. There must be no frills: no unnecessary stroke or line.

A valuable point in which this book differs from most is the emphasis laid on the difference between layout work and the preparation of final product drawings. High standards in both are essential, although the approach to the problems and the attitudes of mind involved are different. Great importance is also attached to facility in rapid and accurate freehand sketching for engineers, a point to which our university engineering schools and technical colleges should pay more attention, if only that they might play their part in training the draughtsmen of the future.

The book is based on American experience, and written in an American idiom. Although conventional practices may differ, it is rather the better on this account, in that a slightly different approach tends to stimulate interest. The extreme importance of precision of thought and clarity of expression is stressed throughout, especially by the space given to the design and use of gauges. The pitfalls awaiting those who try to take short cuts are shown. Little is said about "Design" as such, which is perhaps just as well. It is hard enough to deal clearly with the means by which design is expressed; but the book confirms what seems perhaps to be beginning to be appreciated, that though an engineer need not be a designer, a designer must be an engineer, with plenty of real knowledge of materials, methods, machines, and men, and the talent for applying it.

Although primarily addressed to draughtsmen bent on improving their qualifications, it is a book which every engineer dealing with the creative side of his profession should read. Even if he has been through the mill himself there is always something new to learn. The author is well known in the United States for other books on allied subjects, based on a wealth of both industrial and teaching work.

There is a good index, but no bibliography, and modern "Simplified Drafting," much favoured in some American quarters, does not seem to be mentioned. It is a system which can easily be overdone.

NEW BOOKS

Ideas, Inventions and Patents: How to Develop and Protect Them. By ROBERT A. BUCKLES. *John Wiley and Sons Incorporated*, 440 *Fourth Avenue*, *New York* 16, *N.Y.*, *U.S.A.* (6 *dol*); and *Chapman and Hall Limited*, 37 *Essex Street*, *London*, *W.C.*2. (48*s.*)

The author has written primarily for engineers and scientists engaged in research and development activities and for those planning and managing industrial enterprises in which inventions, patents and trade marks play a role. As a practising patent attorney and member of the New York Bar, the author is naturally concerned mainly with American practice. He deals with what constitutes a patent and why it is necessary; who is entitled to receive a patent; how to plan a patent programme; how to keep records for patent protection; what happens in the patent office; what to do with a patent when it is issued; interference; licences; assignments and shop-rights; how to read and understand patent claims and to recognise infringement; confidential disclosures trade secrets and unfair competition; designs, copyrights and trademarks. The work includes sample forms, patent office drawing symbols and a glossary of terms encountered in patent law.

The Coal Industry of the U.S.S.R. Part 2. Appendix 6. Special Mining Techniques. *National Coal Board*, *Hobart House*, *Grosvenor Place*, *London*, *S.W.*1. (3*s.*)

This publication is the last of a series of seven dealing with the technical mission of the National Coal Board to Russia. It is divided into three sections, dealing, respectively, with hydraulic mining, hydraulic winning with pulsed infusion shotfiring, and flexible sectionless shield support working. The trend in Russia is to reduce coal-production methods to as few operations as possible; this trend is exemplified by hydraulic mining, in which coal is broken down by water under pressure and transported in hydraulic suspension. Costs are much lower than by conventional methods; they approach those of opencast working. Certain types of tough monolithic seams cause the process to lose its profitability, and in such cases, it is better to loosen the coal first by specialised shotfiring.

Flexible sectionless shield support working has been developed for use in steep seams of 8 to 13 ft in thickness. The flexible shield uses a third or less timber, and half the steel required for conventional shields, and can be assembled more easily.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Impact Press. K. S. PAUL LIMITED, Great Western Trading Estate, Park Royal Road, London, N.W.10. The Burger model DO open-gap pneumatic impact press with capacity up to 1½ in; maximum pressure 13,200 lb for an input air pressure of 90 lb per sq. in. Leaflet.

Woodworking Machinery. JOHN PICKLES AND SON (ENGINEERS) LIMITED, Hebden Bridge, Yorks. Comprehensive 200-page catalogue of Ransome-Pickles woodworking machinery, including log saws, bandsaws, frame-saws, circular saws, planers, tenoners, lathes, grinders, adzers, choppers and wood-wool machines.

Kipp Spanners. LORANT ENGINEERS (LONDON) LIMITED, 65 High Street, South Norwood, London, S.E.25. Kipp spanners for machine tools; permanently attached, solid or ratchet types, suitable for threads from $\frac{3}{16}$ to $\frac{3}{8}$ in Whitworth. Leaflet 584/6.

Pneumatic Hammer. B. AND S. MASSEY LIMITED, Openshaw, Manchester 11. "Clear Space" pneumatic power hammer; nine sizes from 2 to 40 cwt, and strokes from 14 to 38 in. Leaflet 5900H.

On the Shelf

By Frank H. Smith

The Swedish Royal Institute of Technology has issued, through its Division of Aeronautics, 42 technical notes (known as KTH Aero Technical Notes). Henceforth these will be issued through the same body's Department of Aeronautical Engineering.

I have a leaflet from Chapman and Hall headed "The reference book of the CENTURY" but as this is followed by the title "Network Synthesis" one must assume that that is the only respect in which it is the reference book of the CENTURY. It will not help you to fry an egg, for instance. This is Volume I, the author is David F. Tuttle (Junior) and the price is £9 8*s.* plus 2*s.* One wonders how far this high pricing can go. True, one expects this sort of money for 1,175 pages, and I suppose firms and (some) libraries can afford such luxurious necessities but it does seem a bit 'ard on the poor individual who wants to check up on the non-dissipative (L-C) one-terminal pair or even on the potential analogy.

That exclusive bunch of Librarians, the Classification Research Group, produced, during 1957, three duplicated Bulletins. These men get together to make the grouping of books so simple that you need a Ph.D. to find any given subject. Anyway, in future their material will be published in the *Journal of Documentation* (Aslib, 40*s.* a year to non-members) beginning with the September issue.

If you are interested in a feature of modern life that is gradually driving us all round the bend, I would suggest you ask Amplivox Limited, 2 Bentinck Street, London, W.1, for a copy of their booklet "Noise in Industry." It is interesting to know that 150 dB make one literally hot under the collar; and I *mean* literally.

From the Information Officer, British Iron and Steel Federation, Steel House, Tothill Street, S.W.1, you can obtain "The Steel Industry's Labour Record" for nothing. There are only five pages but it is an interesting survey of relations in the industry. Labour-work not Labour-politics of course.

British Standards can now be bought over the counter and referred to at Bristol, in a room at the Old Council House headquarters of the Chamber of Commerce.

A remarkable example of cause and effect is given in a recent (No. 48) *Wiggin Nickel Alloys*. An article on salt production in Switzerland reveals that that country produces 90 per cent of its own requirement. The latest machinery uses an Escher Wyss thermo-compression process powered by electricity and using 90 per cent less coal than the old coal-fired pan type. The latter process, however, is the only means by which the coarser cooking salt can be obtained. During the war, coal was hard to come by so the Swiss closed down the older coal-consuming plant. Result—the Swiss housewife has now adapted herself, of necessity, to using table-type salt for cooking!

I wonder why the Canadians cannot make up their minds? In the June number of the *Engineering Journal* there appears a paper entitled "The Corrosion Behaviour of Aluminum (sic) in the Construction Industry." It is by two members of the staff of Aluminium (sic) Laboratories Limited, Kingston, Ontario. If they *are* going to have aluminum, why not behavior? Perhaps the confusion arises from the fact that the paper was originally read at Detroit.

Atomic energy is where the money is. Take, for instance, the Second International Conference on the Peaceful Uses of Atomic Energy to be held at Geneva, 1-13 September. The expected 34 volumes of Proceedings should be ready between December, 1958, and July, 1959, and if you order from HMSO before publication you need only pay £155, instead of about £182.

Automobile Engineering

By Gordon Wilkins

MERCEDES FOR 1959

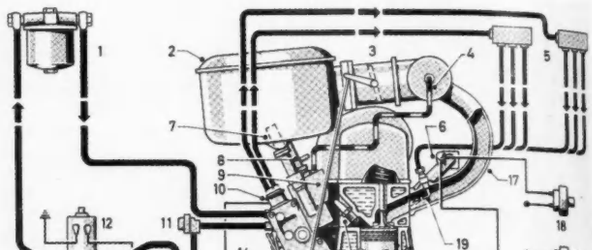
An addition to the Mercedes-Benz range for 1959 is a fuel-injection version of the 220S saloon, which will be known as the 220SE. The engine produces higher torque throughout the speed range and higher maximum power. The object is to increase acceleration rather than speed and it is claimed there is also a slight improvement in fuel consumption.

A new type of injection pump is used with two plungers which provide an intermittent spray of fuel into the inlet ports. The engine also has a different camshaft. The injection pump has twin cams for each plunger and runs at half engine speed. Each plunger feeds a distribution block from which pipes lead to injectors in the inlet ports of three cylinders. This therefore makes three different injection systems now in use on Mercedes-Benz petrol engines. It is simpler, and presumably cheaper and easier to maintain, than the six-plunger injection pumps used on Mercedes 300SL sports car engines, which supply a metered quantity of fuel direct to the combustion chambers, or the similar pump which effects timed injection into the manifolds on the 300 touring car.

There is a direct link from the accelerator pedal to the governor lever on the injection pump, and to the throttle (which is in the main air intake pipe). There is also a centrifugal governor running at half engine speed. A system of cams varies the output of the pump according to both accelerator pedal position and engine speed. Fuel is delivered at a pressure of 215 lb per sq. in. Mercedes-Benz claim that this system gives instant throttle response without the need for an extra acceleration mixture device on the pump. When the driver closes the throttle the governor cuts off the fuel completely, giving an odourless exhaust free of unburned fuel when slowing down or on long descents. The fuel supply is automatically restored if engine revolutions drop below 1,500 r.p.m., so as to ensure jerk-free slow running and even idling.

There are several auxiliary controls in the system. A cold-start solenoid adjusts the control rod to give a rich mixture for starting and automatically cuts out when engine temperature reaches 95° F. A thermostat in the water system adjusts both injection pump and throttle to give fast idle during warming up. Another thermostat inside the air filter reduces the quantity of fuel injected to maintain the correct air-fuel ratio as temperature rises. There is also an altitude "capsule" on the pump to reduce the fuel injected with increasing altitude.

Gross power output is 130 b.h.p. at 5,000 r.p.m., against 120 b.h.p. at 5,200 r.p.m. for the same engine with carburettors. Maximum gross torque is now 146 lb-ft at 3,800 r.p.m., against 137 lb-ft at 3,600 r.p.m. The engine is adjusted to use super grade fuel of 93-95 octane rating and overall fuel consumption is stated to be about 1 m.p.g. better than with carburettors. Fuel-injection cars weigh about 50 lb more than the carburettor models.



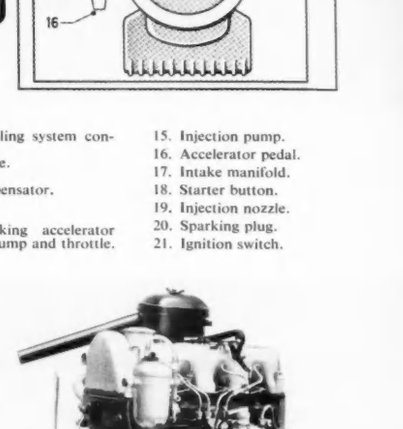
New fuel-injection engine for the Mercedes 220S saloon.

1. Main fuel filter.
2. Air filter.
3. Throttle housing.
4. Idling air bleed.
5. Fuel distribution blocks.
6. Thermostatic switch for cold starting solenoid.
7. Thermostat responding to induction air temperature.
8. Thermostat in cooling system controlling fast idle.
9. Air pressure capsule.
10. Starting solenoid.
11. Fuel pressure compensator.
12. Electric fuel pump.
13. Fuel tank.
14. Control rods linking accelerator pedal-injection pump and throttle.
15. Injection pump.
16. Accelerator pedal.
17. Intake manifold.
18. Starter button.
19. Injection nozzle.
20. Sparking plug.
21. Ignition switch.

Mercedes have unrivalled experience with diesel cars (they have built nearly 100,000 of the 180D engines) and are now extending the range with a new car, the 190D which has a diesel engine of 1,897 cc with overhead camshaft (the 180D of 1,767 cc has pushrod-operated valves). The new engine has greater power and torque than the 180D, maximum gross power being 55 b.h.p. against 46, and it has greater speed range up to a maximum of 4,000 r.p.m. The 190D is said to accelerate from 0-62 m.p.h. in 32 seconds. Maximum speeds on the gears are given as 1st 19, 2nd 33, 3rd 52 and top 75, the latter being a safe cruising speed. Kerb weight is 2,690 lb. The car is generally the same in appearance as the 190D with petrol engine.

As usual, a rubber-mounted sub-frame carries engine, gearbox, front suspension and steering, the gearbox having baulk ring synchromesh for all four speeds. A number of engine parts are interchangeable with those of the 190 petrol engine. Like all Daimler-Benz diesels, the engine uses a pre-combustion chamber with glow plugs for cold starting. Injection is by Bosch pump; cooling by pump, fan and thermostat.

The Mercedes-Benz 300, the largest of the Daimler-Benz passenger cars, will be available for 1959 with power-assisted steering and a full air-conditioning system.



Diesel engine for the new 190D car.

Mercedes Benz 220SE: Engine 6-cyl. ohc. 80 by 72·8 mm, 2,195 cc (133·9 cu. in). Compression ratio 8·7 to 1. Bosch fuel injection into inlet ports by twin-plunger pump. 130 b.h.p. (SAE) at 5,000 r.p.m. Max. torque 146 lb-ft at 3,800 r.p.m. Full-flow oil filter. Oil-water heat exchanger. Electric fuel pump at rear of car.

Mercedes Benz 190D: Engine 4-cyl. ohc. 85 by 83·6 mm, 1,897 cc (115·76 cu. in). Compression ratio 21 to 1. Bosch injection into pre-combustion chamber. Glow-plugs for cold starting. 55 b.h.p. (SAE) at 4,000 r.p.m. Max. torque 83 lb-ft at 2,200 r.p.m. Full-flow oil filter.

The cab of the "Chieftain" has been designed for driver comfort and easy access.

ALBION RANGES AUGMENTED

Two new ranges of goods vehicles have recently been announced by Albion Motors Limited; they are the Chieftain 7 tonners and the Claymore 4 and 6 tonners.

The Chieftain is available in three haulage versions and one tipper, with wheelbases of 10 ft 3 in, 12 ft, 13 ft 6 in and 18 ft 6 in respectively. All are fitted with a five-speed gearbox and optional overdrive, giving road speeds up to 50 m.p.h. On a road test the 12 ft model returned a fuel consumption of 19 m.p.g. when running fully loaded at a speed of 30 m.p.h. Power is supplied by a 5·5 litre engine that has been derated to 90 b.h.p. at 2,200 r.p.m. The drive is taken through a single-plate clutch to the constant mesh box and then to a spiral bevel reduction gear on the back axle. Epicyclic gears in the hubs give a second reduction. Marles cam and double roller steering is employed, and the brakes are vacuum assisted as in other Albion models.

The Claymore models have underfloor engines and are intended for the distributive trades and medium distance haulage. There are five models. The 4 litre engine is a development of the 0·350 range of Leyland engines and produces 72 b.h.p. at 2,200 r.p.m. Engine, clutch and gearbox are built as a unit and are three-point mounted on rubber cushions. There are four gear ratios. Lockheed hydraulic brakes are used. The cab, an all-steel welded assembly, can be entered from both sides and will take two men as well as the driver.

LOTUS FORMULA 1

Lotus cars appearing in Grand Prix races during the early part of 1958 were Formula 2 single seaters with 2 litre engines, but when the 2·2 litre Climax unit became available, Cliff Allison succeeded in bringing one into fourth place in the Belgian Grand Prix at Spa against hot competition. Now the real Formula 1 Lotus has emerged, a lower sleeker machine looking rather like a scaled-down Vanwall—not surprising as Frank Costin worked on body design for both cars.

The debut was with a 1,500 cc engine in the Formula 2 race at Rheims where it was involved in a collision on the starting line which put it out of the race with a punctured oil tank. The 2 litre car suffered from engine trouble. Later two cars with 2 litre engines appeared in the British Grand Prix at Silverstone but one was withdrawn with lubrication trouble and the other with overheating. However, development continues on this newcomer which on appearance, design and performance potential makes a highly interesting addition to the Grand Prix scene.

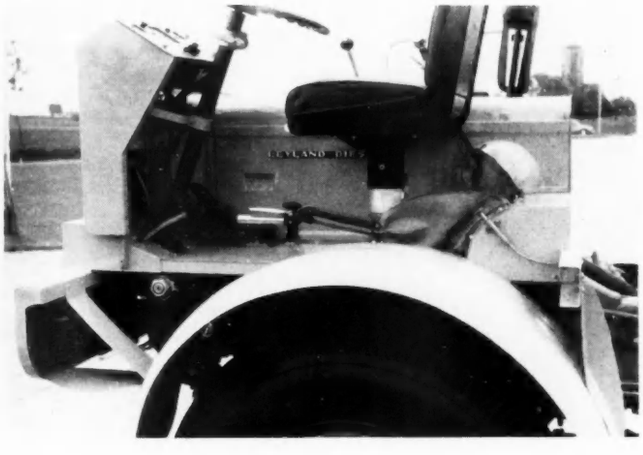
Front suspension follows the standard Lotus arrangement with an anti-roll bar forming part of the top wishbone; the Chapman strut-type independent suspension is used at the rear. Armstrong coil spring damper struts are used all round. The light space frame is similar to that of the Formula 2 car but wider, and is enclosed in a beautifully streamlined body which is extremely low built, the highest point being the driver's headrest which is only 37 in from the ground. The wrap-round windshield is an unusually close fit and it is fortunate that Lotus team drivers are generally small and slim because it would be difficult for a stout driver to get into the car at all. Originally the engine was to be laid on its right side as in the Lotus 15 sports cars and this was adopted on the first of the new single seaters, but the curved induction pipes required in this position caused some loss of power. The second car therefore has the engine canted slightly to the left as on the works sports cars at Le Mans. A blister is necessary to cover the exhaust cam box with this arrangement and it seems to have caused an unexpected disturbance to air flow on the sports car, but may not be so serious on the single seater where air flow is disturbed anyway by the exposed wheels. The exhaust system is fully enclosed within the body, giving the car cleaner lines than any other Grand Prix car now racing.

An interesting 5-speed gearbox and differential have been combined in an entirely new layout at the rear of the car. The gearbox now lies alongside the driver on his left side and the drive is transferred to the differential by a pair of spur gears. On the car with reclining engine, the drive shaft passes straight back from engine to gearbox on the driver's left. On the car with the near-vertical engine the drive shaft passes under the driver's left leg and the gearbox differential unit is set at an angle of about 4° to the wheel axes in both plan and elevation.

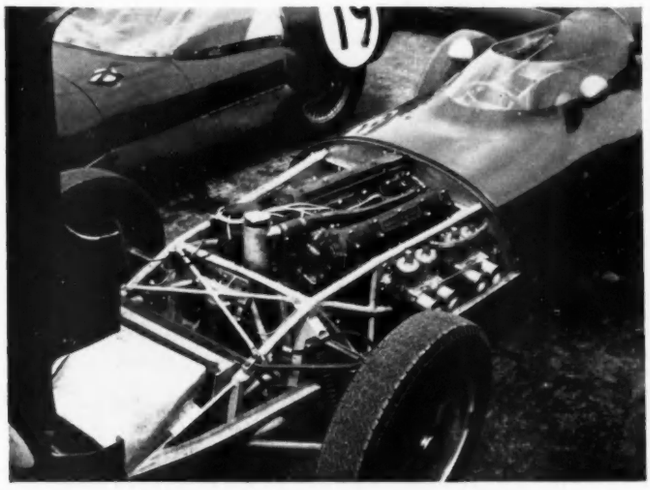
At Silverstone, drivers were suffering from hot seat produced by heat transferred from the gearbox-final drive despite an asbestos covering on the gearbox; a special ventilation system seems to be needed. In the gearbox the first speed pinions act as the oil pump to lubricate the unit and weight of the final drive assembly is 3 lb below that of the unit on the Formula 2 car.

At present an electric starter is mounted on the engine owing to the difficulty of providing external access for a starter shaft. A small heat exchanger on the front of the engine transfers heat from engine oil to water in the cooling system, supplements and the oil radiator that consists of two light alloy tubes in a reverse-flow duct along the left side of the chassis.

The engine is a 4 cylinder model of 88·8 mm bore and stroke giving a capacity of 2,210 cc. The compression ratio is 11 to 1 and the power developed is 190 b.h.p. at 6,250 r.p.m. Two twin-choke SU carburettors are fitted, and the one twin overhead camshaft. The transmission is by twin plate dry clutched rear mounted five-speed gearbox with quick-change ratios for 3rd, 4th and 5th speeds. Spiral bevels are used for the final drive. The wheelbase is 88 in; track, front and rear, 47 in; length, 140 in; width, 54 in; and height, 37 in. Weight not revealed. The Girling disc brakes are 9 in diameter. Bolt-on disc wheels in light alloy are standard. Rack and pinion steering is employed.



Alternative Engine Positions



Single seater Formula 1 Lotus.

NEW GUY COMMERCIAL VEHICLES

A new range of four, six and eight-wheeled commercial vehicles, the "Invincible Mk II" produced by Guy Motors Limited, for gross weights from 14 to 24 tons, incorporates several mechanical advances and unusually comfortable crew accommodation.

Both clutch and accelerator are hydraulically operated and hydraulic power assistance for the steering is optional. A cam and plunger limited-slip differential, first of its type to be adopted on a British goods vehicle, is available as third differential on double-drive bogies; it has the merits of the manually locked type, maintaining the drive to one axle even if the wheels of the other are off the ground, but has no separate control which could be forgotten. On eight wheelers the brakes on first and third axles have a separate circuit from those on the second and fourth and the handbrake is of new design, employing an air cylinder to take up initial slack, so as to give the power of a multi-pull brake with a single pull and no time lag. Four and six wheelers can have forward or conventional control and the wide range of diesel engines available includes Gardner 6LW and 6LX, Leyland 600 and 680, Rolls-Royce C6, Meadows 6DC500 and 630 and British-built Cummins.

Features of the driving cab include curved windscreen, swivelling quarter lights, heater and demister, four headlamps independently focused for distant or dipped lighting, an exterior visor, plug socket for electric razor and a cigarette lighter.

CONTINENTAL ADAPTATIONS

Standard Leyland trucks have been converted to conform with Dutch and German regulations by Leyland-Holland N-V the associated company. One modification is the fitting of Pneumo-Cyclic gearboxes giving fully automatic control of gear-changing. This is believed to be the first time that the control has been fitted to goods vehicles. The second modification is the alteration to cab-over-engine design with left-hand steering. The change enables a longer useful body to be incorporated while yet remaining within the length limitations now current in Germany. These are 42 ft 8 in over all for tractor and semi-trailer and 46 ft for truck and trailer.

Continuing
Automobile Engineering

THE TYPHOON

The 60 per cent purchase tax on cars in England is leading to a growing build-it-yourself movement. There are, in fact, enthusiasts who are building their own sports cars. Latest effort to meet their needs is the Typhoon, developed by two young engineers, Bill Woodhouse and Anthony Bullen, using low-cost Ford mechanical parts. Chassis frame is of 3 in diameter tubes

Built at home from tax-free items, the Typhoon has a glass fibre body on a tubular chassis.

with sub-frame of smaller diameter. Independent front suspension is achieved in the familiar way by cutting the Ford Popular axle in two, pivoting the two halves at the centre and using the normal radius arms in conjunction with Armstrong coil springs and telescopic dampers. The Ford 1172 cc side valve engine, three-speed gearbox, torque tube, drive shaft, rear axle, wheels and brakes must be supplied by the person building the car. The chassis frame passes under the axle at the rear and is located laterally by a Panhard rod, suspension again being by coil springs and telescopic dampers. The body consists of eleven mouldings in resin-bonded glass fibre, including floor, and front and rear bulkheads. There are two versions, a two-seater on an 87 in wheelbase and an occasional four-seater, with two tiny rear seats suitable for children, on a 97 in wheelbase. The designers hope to begin production shortly at Tornado Cars Limited, Rickmansworth, Hertfordshire.

Chassis frame with pedals, attachment brackets, suspension units, Panhard rod and remote control for the gearbox including the adaptation of front axle, costs £70. Set of body mouldings costs £130. Engine, gearbox, transmission, wheels, brakes and electrical equipment can be obtained cheaply by breaking up a secondhand car, but it must be admitted that they are rather expensive at the prices the car manufacturers charge for new spare parts. (The retail price of the necessary Ford parts in England is about £200.)

A short road trial showed that the car has a lively performance even with the engine in standard trim, and it is stable on corners with little roll, the Ford Popular mechanical brakes should deal adequately with a car weighing about 1,400 lb. The suspension is not very supple (it could hardly be with a chassis which passes under the axle at the rear), but even so, on the four-seater version fully loaded, it was easy to strike the exhaust system on the ground on a rough road and the car certainly needs more ground clearance than has been provided on the prototype.

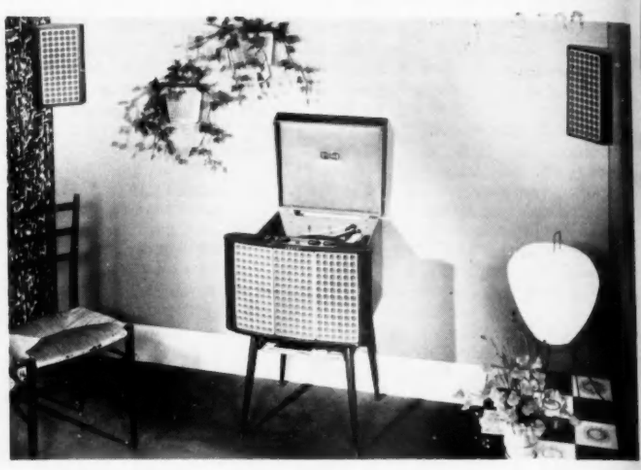
Engineering at Home

STEREOPHONIC TRANSMISSIONS

The BBC have decided to carry out a further series of experimental stereophonic transmissions, starting in October. It is likely that there will be a transmission between 11 a.m. and 12 noon every other Saturday. Third Programme transmitters in the medium and VHF bands will carry the left-hand channel and the television sound transmitters will carry the right-hand one. During May, similar transmissions were broadcast, and many listeners reported they had obtained an impression sound perspective.

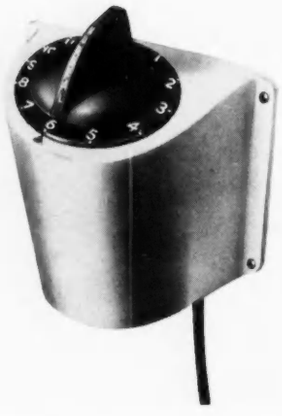
Although the experiments require a separate transmitter and receiver for each channel (ENGRG., 14 Feb., p. 224, and 2 May, p. 576, 1958), the BBC is studying methods of transmitting stereophonic programmes from a single VHF transmitter. If it is found possible to introduce such a system, the necessary receiving apparatus will include twin amplifiers and loudspeakers such as are already available for reproducing stereophonic discs or tapes. An example of such equipment is the " Stereogram " SG188 manufactured by Decca Radio and Television, 1-3 Brixton Road, London, S.W.9. It will play all types of discs and is equipped with an automatic changer with two pick-up heads. Twin 6 watt amplifiers are incorporated, having coupled bass, treble, and volume controls, and a concealed balance control. As can be seen in the illustration, the unit is equipped with three loudspeakers.

During the next few months, the BBC will be collaborating with Electrical and Musical Industries Limited, Hayes, Middlesex, in tests of a transmissions system invented by the company. Basically, EMI's Percival system involves separating the information about the direction the sound comes from, from the sound itself. At the receiver, the directional signal operates on the programme signal to produce the stereophonic effect through two loudspeakers.



Although the proposed BBC stereophonic experiments require a separate transmitter and receiver for each channel, methods of using a single transmitter are being studied. If such a system came into use, the receiving apparatus would include the twin amplifiers and loudspeakers of present stereophonic record players.

Since only a very narrow frequency band is required for the directional information, virtually all the bandwidth remains available for the programme itself. The system is fully compatible, and a listener with a normal set will obtain a satisfactory monaural signal while his neighbour with a stereo receiver hears the same programme in stereophonic sound. The radio part of the stereophonic receiver is said by the company to be only slightly more complex than an ordinary radio set.



WARM RETURN

A time switch is now being produced by Hurseal Limited, 229 Regent Street, London, W.1. It is designed primarily to operate with oil-filled radiators and will control up to 15 A. It can be set to switch at times of up to 12 hours and thus allows the radiators in a room to be switched on before the occupants return. However, time switch controls of this sort are recommended only for use with electrical appliances with totally enclosed elements and inherent safety from fire risk. A coiled spring operates the switch; setting the control pointer automatically adjusts the tension of the spring. The switch can be screwed permanently to the skirting board adjacent to the 13 A or 15 A plug it is to control.

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